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Periodontology, Oral Surgery, Esthetic & Implant Dentistry Open

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Aims and Scope of the POSEIDO Journal

The POSEIDO journal focuses on all aspects of the interconnected clinical and research fields of periodontal sciences, oral and cranio-maxillofacial surgery and medicine, esthetic and restorative dentistry, with a particular interest in implant dentistry, and related research.

Most publications are connected to the dental and maxillofacial field, but some are also from orthopedics, material sciences or other scientific disciplines interconnected with the POSEID research topics (e.g. bone implantable materials, bone regenerative medicine strategies), in order to promote transversal translational research.

POSEIDO is organized as an info journal (international forum), and is therefore publishing a significant quantity of editorial material, as a basis of information, debate and discussion for our community. This editorial material takes particularly the form of **clinical case letters** and **research letters**.

The objective of this strong editorial section is to create links between international research teams, to organize our international research community and to develop a neutral international platform for the publication of debates and consensus conferences in the fast-growing and evolving fields of the POSEID disciplines.

The journal is also publishing a classical content with full-length articles (**original articles and reviews**), following a strict double peer-review process. The journal is particularly interested in original research articles and clinical studies about new techniques, biomaterials and biotechnologies with direct clinical applications in the interconnected fields of periodontology, oral surgery, esthetic and implant dentistry. Review articles are also welcome if they make the clear synthesis of debated topics.

Detailed guidelines for authors can be found on http://www.poseido.info

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Editorial

A clinical round table about the treatment of the severely resorbed posterior mandible. Part 1: challenges, endeavor and perspectives

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Implant dentistry evolved and improved very quickly during the last 15 years, and the Frontier of the rehabilitation strategies is each year pushed further. However, there is one very common clinical situation that remains quite complex to treat even for the experienced clinicians: the severely resorbed posterior mandible. After teeth extraction, the centrifuge resorption of the alveolar bone is quite quick and it remains only a dense cortical bone. The presence of anatomical obstacles - mostly the mandibular inferior nerve - and the general shape and orientation of the residual bone mandibular body, often compromise a functional and stable implantation in this area after natural resorption. The problem is often solved in full arch mandibular rehabilitation through the use of implants in the anterior region and a prosthetic cantilever to rehabilitate the posterior area, but this approach is not possible when the patients still have healthy anterior mandibular teeth and only need posterior rehabilitations.

The use of short implants gives excellent result in moderately resorbed posterior mandibular ridges **[1]**, but resorption can very quickly reach the limits of what short implants can do. If a bone reconstruction is required, this mandibular cortical bone is dense and often not well vascularized, what makes difficult to regenerate some bone chamber or to graft a material on the mandible body. Moreover, the specific dynamic of the mandible body implies many constraints both intrinsic and extrinsic on the posterior bone body, what are supplementary sources of interferences with a potential bone regenerative therapeutic strategy.

Many techniques have been suggested to treat this area, but all of them remain quite complex: for example, inferior alveolar nerve transposition or by-pass **[2]**, distraction osteogenesis **[3]**, ridge lateral expansions **[4]**, segmental osteotomies **[5]**, Guided Bone Regeneration (GBR)**[6]**, onlay or particulate bone grafts **[7]**. Based on the literature, we can not find any consensus on what would be the ideal treatment for this area, as most of the potential techniques remain relatively experimental and done on small series.

In this issue of the POSEIDO journal, we started to ask their opinion to a group of renowned clinicians worldwide, on how they would treat a severely resorbed posterior mandible, based on their long experience and clinical daily practice. The objective of this series of articles in the POSEIDO journal is to highlight many different surgical techniques or strategies - some of them have never been published before - to perform an implant-supported fixed rehabilitation on severely resorbed posterior mandibular alveolar ridges, and

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to discuss the advantages and disadvantages of each of them, in order to reach finally a form of consensus conference between experts. These articles will take mostly the form of clinical case letters illustrating and debating new approaches, and they will lead to roundtables between experienced clinicians.

In this first series of letters, we mostly focused on the concept of Screw-Guided Bone Regeneration (S-GBR). This is actually a quite general concept that finds applications in many areas: the GBR barrier delimitating the bone regenerative compartment is supported by screws (osteosynthesis screws or even the dental implants) serving as space maintainers and supporting pillars for the bone regeneration. This approach was de facto used in many sinus augmentation procedures **[8]** and in various forms of guided bone regeneration since many years, even if this concept was never really duly isolated from other forms of GBR. **In this issue, we tried for the first time in the literature to isolate, define, illustrate and refine this specific concept of S-GBR, and to show how it can bring interesting clinical therapeutic solutions to the treatments of the resorbed posterior mandible.** Some other approaches such as the nerve by-pass or the sandwich technique were also described, and this will be illustrated further in the next issue.

This series of articles also highlighted 2 very important elements in these regenerative strategies. The first key element is the absence of consensus on the choices of bone materials **[9]**, resorbable or non resorbable membranes and even implant design and surface **[10]**. The literature is very large but very controversial and commercial on this matter **[9,10]**, and it is impossible to get a clear and scientifically validated information of what should be used, in which situation, particularly in complex cases of severely resorbed posterior mandible. For now, we have decided to read the various suggestions of combinations that were validated by the experience of some clinicians, but it is an objective of POSEIDO to reach a real first consensus on this matter in the future.

The second key element that appears in this roundtable is the development of the systematic use of Leukocyte- and Platelet-Rich (L-PRF) membranes **[11]**. L-PRF is a platelet concentrate for surgical use, defined as an autologous fibrin matrix enriched in platelets, leukocytes and growth factors and obtained after centrifugation of 10 mL blood samples **[12]**. The technique is easy and inexpensive, and after compression of the L-PRF clots, many L-PRF membranes can be collected and used in oral surgeries. L-PRF was largely used in some countries like France and Italy since more than 10 years, but the technique only started to develop recently worldwide, due to confusions with the Platelet-Rich Plasma (PRP) families that have been almost abandoned in the oral and maxillofacial field. L-PRF membranes strongly stimulate bone and soft tissue healing **[13,14]** and can be easily combined with many materials and membranes to improve the current techniques **[7,15]**. For the treatment of the posterior mandible, these membranes offer new opportunities to improve and simply the treatments, particularly through the improvement of soft tissue healing and maturation and the reduction of the risk of gingival flap dehiscence above the bone regenerative chambers.

The development of new techniques in the treatment of the resorbed posterior mandible is therefore only at its early steps, and we hope that this overview of new techniques will lead the POSEIDO network to define a first consensus and maybe new therapeutic standards in the future.

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Special Review: Clinical Round-table

The concept of Screw-Guided Bone Regeneration (S-GBR). Part 1: from sinus-lift to general applications in the resorbed maxilla and mandible

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Abstract

The concept of Guided Bone Regeneration (GBR) is quite old and is now covering a large quantity of techniques and combinations of grafting materials and resorbable or non-resorbable membranes. For the treatment of the resorbed posterior mandible, the efficiency of the GBR concept is relatively difficult to fully validate, as it remains difficult operator-dependent techniques where no consensus on the material combination exists. The terminology used in the literature is quite confusing about these techniques, as it covers in fact many different approaches. In this article, we isolate and describe for the first time one very specific approach named Screw-Guided Bone Regeneration (S-GBR), where the osteosynthesis screws and/or screw implants are used as pillars of the bone regenerative compartments during GBR strategies. We show that this particular version of GBR in fact covers transversally many techniques of bone grafting and regeneration which have in theory very little in common, particularly the posterior mandible lateral ridge augmentation and the simultaneous sinus-lift and implantation. We also describe one new approach of pure S-GBR for the treatment of the resorbed posterior mandible based on a 5-year experience with this technique using L-PRF (Leukocyte- and Platelet-Rich Fibrin) as healing and interposition material.

Keywords. Bone grafting, dental implants, fibrin, Platelet-Rich Plasma, sinus floor augmentation.

1. Conceptual evolutions: from GTR to GBR

The concept of Guided Bone Regeneration (GBR) is relatively old. Historically, it started with the development of the concept of Guided Tissue Regeneration (GTR) in periodontology for the regeneration of periodontal tissues around compromised teeth **[1]**. The theoretical biological principles of GTR are that proper periodontal healing requires to separate the bone and gingival compartments by the mean of a barrier during the wound

tissue healing **[2-4]**, in order to prevent the migration of non-desirable cells (particularly gingival fibroblasts and other soft tissue cells) into the bone compartment. Indeed, after the treatment of an intrabony periodontal lesion, the quickest cells to grow and colonize the curetted bone cavity are the soft tissue cells, and the creation of a fibrous tissue around the teeth is blocking the needed bone regeneration of this space **[1]**.

Many versions of this GTR concept have been developed, using various forms of barrier membranes (resorbable or non-resorbable) and the curetted periodontal defects can be filled with only a natural blood clot, with harvested autologous bone or with a bone substitute (allograft, xenograft or synthetic materials)**[5,6]**. The various forms of these techniques are nowadays well documented and a common approach used in periodontal surgery, even if there is a lack of consensus on the ideal filling material and membranes to use.

The concept of GTR was advocated as a general therapeutic concept to be extended to many forms of tissues or situations. However, very quickly after the first development of GTR, the concept of GBR was advocated as a more "bone centered" version of the GTR concept **[7]**. If GTR was kept as a periodontal treatment concept around teeth, GBR was extended to all bone lesions that require regeneration, particularly for pre-implant surgical bone reconstruction or peri-implant bone regeneration **[8-10]**. The basic biological principles are the same: to prevent soft tissue invagination and protect the bone regenerative compartment during bone healing from the migration of non-desirable cells.

One of the main practical differences between GBR and GTR was that the volumes of tissue to regenerate with GBR were clearly much larger that the volumes involved in GTR, what deeply changed the technical approaches and materials to use between the 2 techniques. Indeed, extended GBR techniques imply a significant risk of failure because of higher mechanical constraints on the regenerative chamber (particularly related to the extended surgical site and the absence of protecting teeth around the site) and the risk of soft tissue dehiscence around extended surgical flaps.

To reach good and predictable clinical results, many kinds of barriers membranes have been tested for GBR **[11]**. The use of non-resorbable membranes (titanium mesh, ePTFE - expanded polytetrafluoroethylene membranes, etc) is a quite traditional and pure approach of GBR **[12,13]**, as it allows to have a rigid protection of the regenerative bone chamber and sometimes to perform the bone regeneration with blood as sole grafting material. Unfortunately, these membranes are difficult to use and can bring complications such as soft tissue dehiscence during the healing period and membrane bacterial contamination**.** In addition, membrane removal during implant placement requires an extensive surgical exposure of the newly formed bone. Resorbable membranes (collagen, polylactic acid, etc) are easier to use and are very frequent nowadays **[14-16]**, but they rarely provide enough protection and stability for the bone grafted material (particularly particulate bone grafting material) and their indications have to be selected carefully. The adequate combination of grafting material, membrane and surgical technique remains an important field of debates and research **[17-20]**.

2. From GBR to S-GBR

The concepts of GBR were in fact applied and included in many other techniques, particularly in the various forms of bone grafting **[21]**, distraction osteogenesis **[22]**, segmental osteotomies **[23]** and alveolar ridge lateral expansion **[24]**. Even if these techniques are using their own bone regeneration principles, all are based on the concept of

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preparation of a bone regenerative compartment (in general filled with a bone materials) and protection from gingival invagination through the use of membranes.

Many forms of bone grafting procedures were developed in the last years in order to reconstruct alveolar ridges suitable for implantation. Sinus floor augmentations were probably the most described techniques among all, as it represents a very frequent and safe treatment of the posterior maxilla, with the axial **[25]** or with the lateral approach **[26]**. In the classical surgical procedure using a lateral approach, the sinus membrane is lifted, the prepared cavity is then filled with a bone material (autologous bone, allograft, xenograft or synthetic)**[27]** and implants can be placed some months after the maturation and integration of the bone graft **[26]**. There is a consensus **[28-30]** that most biocompatible materials are functioning well in sinus floor augmentation procedures (even if each material requires different healing time and offers different histological results)**[27,31]**, but it is often recommended to cover the access lateral window with some barrier (membrane or bone fragment) in order to avoid the soft tissue invagination within the sinus cavity **[26]**. This recommendation follows the principles of GBR.

The alveolar ridge lateral augmentation procedures are also based on bone grafting with various materials associated with the use of membranes of interposition and protection, and are often following the GBR concepts. A famous technique of lateral augmentation is the combination of deproteinized bovine bone graft and porcine collagen membrane **[21,32]**, but many options exist such as the combination of allograft (in small particles or in bone blocks) with collagen membranes and/or L-PRF (Leukocyte- and Platelet-Rich Fibrin) membranes **[33,34]**. The use of healing and interposition membranes in this kind of surgery is almost always needed and recommended **[35]**.

Alveolar ridge lateral expansion is also a form of GBR, as this technique requires to split the alveolar ridge and to expand it laterally to gain some bone width prior to implant placement **[36]**. In this technique also the bone chamber can be grafted with various bone material and must be protected by some barrier membranes of interposition between the bone and the gingival compartments. Simultaneous implant placement is often needed, as the implants serve as space maintainers between the 2 segments of the split alveolar ridge after expansion **[24,37]**.

All these techniques can be performed prior to the implantation surgery – and they were described initially as a pre-implant surgical step for bone reconstruction. However with the recent improvements of implant design and surfaces (and the strong reduction of implant prices)**[38]**, the simultaneous bone reconstruction and implantation is a relatively frequent approach. It started with the traditional GBR itself, where the simultaneous implantation allows to use the implants as tent pegs reinforcing mechanically the resistance of the bone regenerative compartment against parasite constraints **[12,14,39,40]**. This concept of implants as supporting screws was also extended to sinus floor augmentations **[41]**, alveolar ridge lateral expansions **[24]** and other applications.

These evolutions of implantation created a new approach of GBR. Implants are screws with improved design and surfaces, and can be considered as optimized large osteosynthesis screws. If these screws are used as tent pegs or supporting regenerative pillars in many surgeries in order to maintain and protect the bone regenerative compartment, then they logically impact the way bone is guided and regenerated. This introduced the concept of Screw-Guided Bone Regeneration (S-GBR).

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3. Sinus-lift with simultaneous implantation, the S-GBR illustrated

Extended sinus floor augmentations using the lateral approach with simultaneous implantation became recently a good illustration of the S-GBR concept. Several authors advocated that implants could be placed without risk at the time of the sinus-lift bone graft, as long as it was possible to stabilize them in the residual bone ridge **[41-44]**. As the consensus raised that most bone grafting materials were efficient in the sinus due to the osteogenic properties of the Schneiderian membrane **[27-30]**, some authors suggested to perform the sinus-lift without grafting material **[45-47]**: the sinus membrane was lifted and maintained in position by the tips of the implants serving as tent pegs. The space between the residual alveolar bone and the membrane was then filled with a natural blood clot and the implants served as pillars for the mechanical protection and stabilization of the sinus membrane in high position. In general, it was recommended to keep the bone fragment of the lateral sinus window and to replace it in its initial position in order to close the sinus regenerative compartment as a natural interposition GBR barrier to avoid soft tissue invagination. The use of another membrane of interposition was also possible if the fragment was lost or left as the new sinus floor after the membrane lifting.

This approach revealed excellent results and also highlighted more physiological results than the traditional sinus-lift with grafting material. Indeed, the use as blood clot as sole filling material allowed to keep the periosteum of the Schneiderian membrane exactly at the level of the tip of the implants and the final bone regeneration of the cavity was done exactly at the size of the future implants, far from the often excessive und uncontrollable volume of sinus floor graft performed with a traditional filling material. This was particularly useful to avoid obstruction of the sinus meatus or non physiological bone grafted volume that can affect the sinus air circulation.

In order to improve this approach, several articles described and validated the long-term results of the use of L-PRF (Leukocyte- and Platelet-Rich Fibrin) clots and membranes as sole grafting material within the sinus cavity **[48,49]**. L-PRF (marketed as Intra-Spin L-PRF system, Intra-Lock, Boca-Raton, FL, USA) is a platelet concentrate for surgical use of the PRF subfamilies **[50]**. After centrifugation of whole blood without anticoagulant, a fibrin clot enriched with platelet, leukocytes and growth factors can be collected for implantation **[51]**. After collection and compression in the Xpression L-PRF Box (Intra-Lock, Boca-Raton, FL, USA)**[52]**, large and strong fibrin membranes for surgical use can be obtained to improve healing **[53,54]**. These membranes contain most of the platelets and half of the leukocytes (mostly lymphocytes) of the initial blood sample **[51]**. They release significant quantities of platelet growth factors (Transforming Growth Factor β1 TGFβ1, Platelet-Derived Growth Factors PDGFs, Vascular Endothelial Growth Factors VEGF)**[55]** and other healing proteins (thrombospondin-1, fibronectin, vitronectin) during at least 7 days in vitro **[56]**, and offered strong proliferation and differentiation stimulation on several cell types (osteoblasts, bone mesenchymal stems cells, fibroblasts, etc) in vitro **[57,58]**. L-PRF can be considered as an optimized blood clot and is therefore an ideal material to replace a natural blood clot within a sinus cavity **[35,59]**. It is also considered as a resorbable barrier that can be combined with GBR techniques **[60]**.

In this surgical procedure, the sinus membrane was lifted carefully **(Figures 1A to 1C)**, and then covered and reinforced with a L-PRF membrane. The implants were placed and their tips were maintaining the Schneiderian membrane with L-PRF membrane in high position. The new sub-sinus cavity was then filled with several L-PRF clots placed directly around the implant **(Figure 1D)**. The lateral window was then closed to avoid soft tissue

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invagination and the use of L-PRF membranes was reported **[48]** as a sufficient barrier to fulfill this function in this clinical situation **(Figure 1E)**. Six months after surgery, the sinus floor bone was partially regenerated and strong enough to place the implant-supported crown. On the radiographic follow-up, the regenerated volume was not completely mineralized, but the new sinus floor was already stabilized just above the implant tip **(Figure 1F)[49]**.

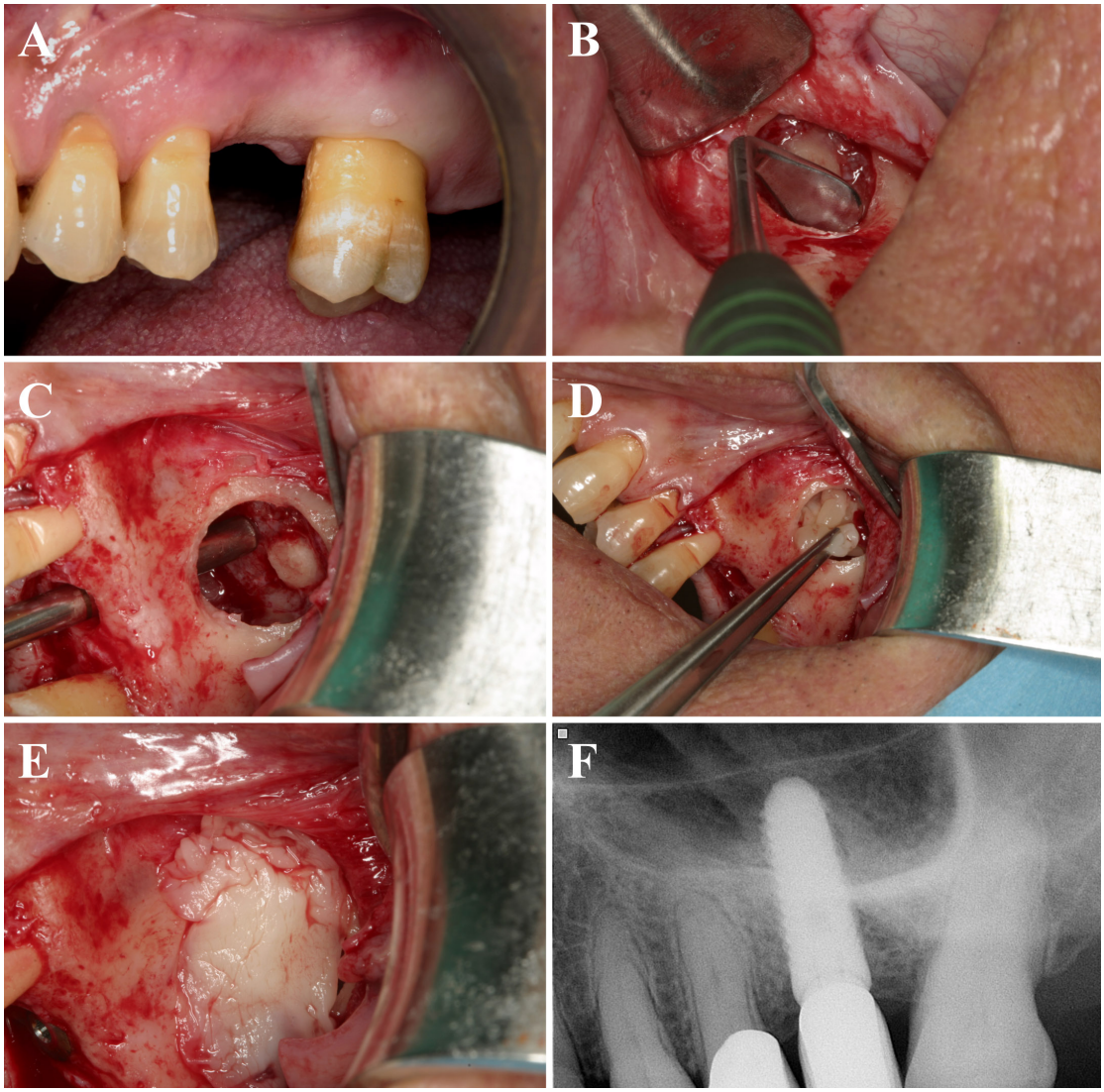

Figure 1. Sinus floor augmentation procedure with simultaneous implantation and L-PRF as sole grafting material. (A) Initial situation. **(B)** The sinus membrane was lifted and the lateral bony window was left in position to serve as new reinforced sinus floor. **(C)** Implant osteotomies were performed and the final step was managed with a manual osteotome. The sinus membrane was covered with a L-PRF membrane and the implant was placed to maintain it in high position. **(D)** The sub-sinus cavity was then filled with four L-PRF clots. **(E)** The lateral window of the sub-sinus regenerative chamber was then covered with 2 L-PRF membranes to protect the compartment and avoid soft tissue invagination. **(F)** Six months after surgery, the implant-supported crown was placed and the radiographic follow-up showed the new sinus floor limit and the bone regeneration on progress of the sub-sinus space.

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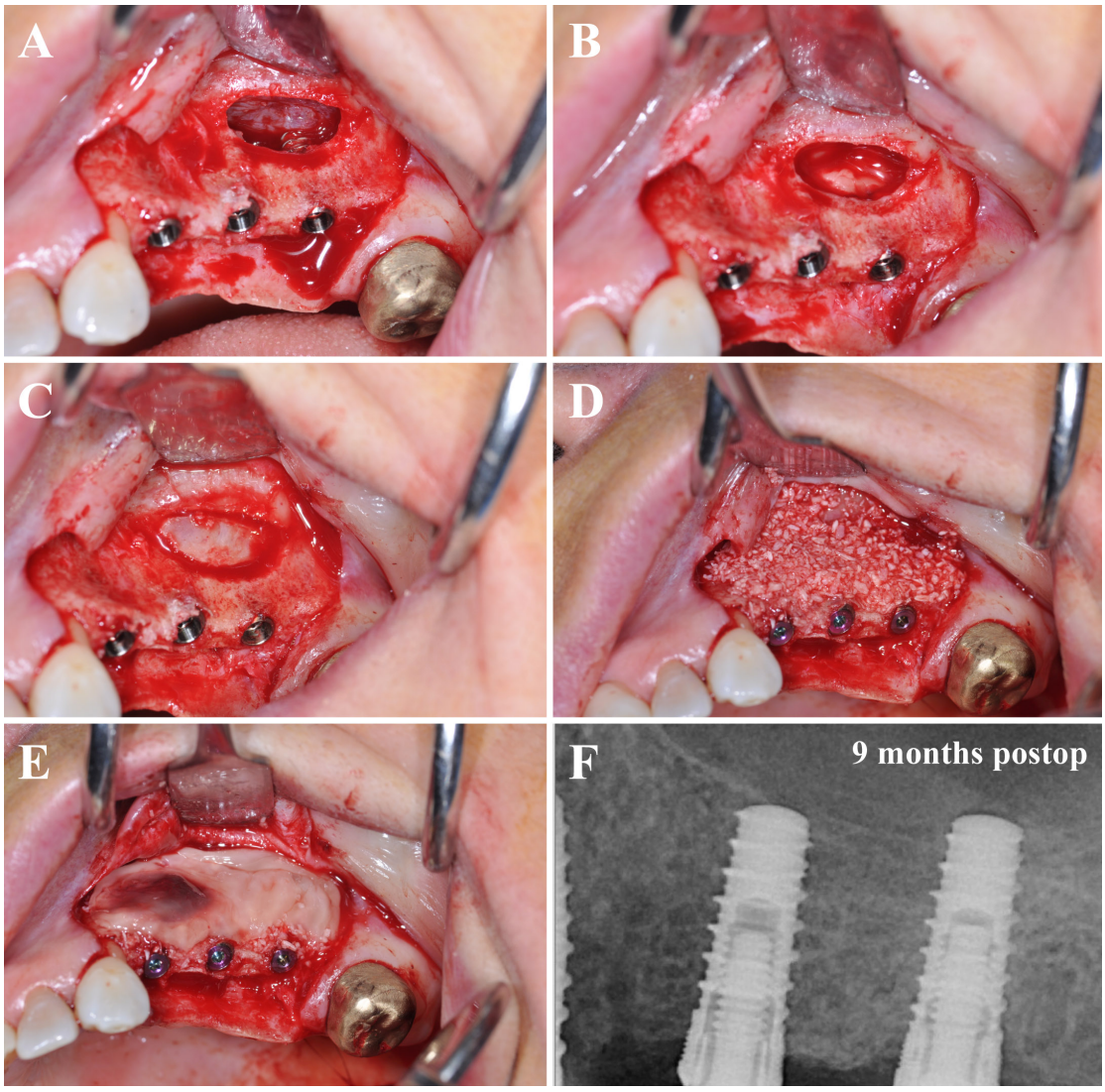

Figure 2. Sinus floor augmentation procedure in the severely resorbed maxilla with simultaneous implantation and L-PRF as sole grafting material, combined with alveolar ridge lateral augmentation. (A) The sinus membrane was lifted after removal of the lateral access bony window, and was covered with 2 L-PRF membranes for healing and protection. Three Ossean implants with micro-threaded collars (Intra-Lock, Boca-Raton, FL, USA) were then blocked in the residual sub-sinus alveolar bone height and their tips served as tent pegs to maintain the sinus membrane and L-PRF membranes in high position as the future sinus floor. **(B)** The sub-sinus cavity was then filled with 6 L-PRF clots. **(C)** The sub-sinus cavity was then covered with the initial bone window fragment, as a natural barrier for the regenerative chamber. **(D)** The area was then grafted with a bone grafting mixture of L-PRF and xenogeneic collagenated bone (Gen-Os, OsteoBiol, Tecnoss, Italy) following a 50/50 volume mix ratio. **(E)** The whole surgical site was covered with 2 layers of L-PRF membranes as healing and interposition membranes, and was then sutured. **(F)** The clinical and radiographic follow-up after 9 months revealed a natural bone regeneration of the sub-sinus cavity.

This L-PRF technique can also be combined with other forms of GBR, such as alveolar ridge lateral augmentation, and gives excellent results on the maxilla **[35]**. In this case of severely resorbed posterior maxilla, the sinus membrane was lifted, covered with a L-PRF membrane (as protection and healing material) and maintained in high position with the tips of the implants **(Figure 2A)**. Three Ossean implants with micro-threaded collars (Intra-

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Lock, Boca-Raton, FL, USA) were used here as the implants needed to be stabilized immediately in the residual sub-sinus alveolar bone height **[49]**. The sub-sinus cavity was then filled with 6 L-PRF clots **(Figure 2B)**, and closed by replacing in initial position the residual bone fragment of the lateral osteotomy **(Figure 2C)**. The alveolar ridge was then grafted laterally with a mix of L-PRF and bone biomaterial **(Figure 2D)**, and the whole grafted area was covered with 2 layers of L-PRF membranes **(Figure 2E)** and sutured. Nine months after surgery, the radiographic follow-up showed very well the sinus bone regeneration up to the tips of the implants **(Figure 2F)**.

The cases described above illustrate the advantages of the modified S-GBR approach in comparison to other forms of GBR. In S-GBR, the bone is directly regenerated around the screws serving as tent pegs and space maintainers of the regenerative volume, and this allows to tailor the regenerative volume exactly to what is needed for the success of the treatment. The new sinus floors are always exactly at the tip of the implants **[49]**. Moreover, as the implant screws serve as pillars for the growth of the implants, we can expect that the process of osseointegration is developing directly on the implant surfaces in the most physiological bone orientation and without the interference of any grafting biomaterial: this is a natural bone chamber model. Following our own experience since 8 years **[48,49]**, we never lost any implants using this form of S-GBR in sinus-lift, even in extremely resorbed maxillary cases. This may be explained by the significant quality of the natural bone regeneration process in this type of surgery. This observation raises new possibilities in many other clinical situations.

4. The new Frontier: pure S-GBR for the reconstruction of the severely resorbed posterior mandible

GBR techniques give excellent results in the maxilla, but the treatment of the severely resorbed posterior mandible remains difficult with this approach. The mandibular bone is very cortical and the integration of a bone grafting material or the regeneration of an implantable bone volume in this area remains a challenge. The literature remains scarce, even if some interesting results of GBR were reported **[61]**. Many techniques can offer interesting results, but there is no real consensus. Distraction osteogenesis **[62,63]**, segmental osteotomies **[23,64]** or lateral ridge expansion **[24,36]** are difficult surgeries and have indications only when the ridge anatomy is compatible. The risk of complications is significant due to the risk of soft tissue dehiscence above the regenerative compartment. The concept of S-GBR with L-PRF seemed therefore an interesting therapeutic strategy.

In this first approach that we started to develop 10 years ago, the S-GBR was mostly applied to the lateral thickening of thin mandibular alveolar crests, in order to rebuild bone width. In this early phase of our technique, we were mostly using a combination of bovine bone, resorbable membranes and non-resorbable membrane with long periods of healing, in order to perform this type of complex bone regeneration. The reconstruction of bone both vertically and horizontally (crestal width and height) is more complicated and requested – from our experience - to use different kinds of materials, particularly bone materials with quicker resorption, integration and turn-over, and the massive use of L-PRF.

This article is the first description of this technique in the literature and this case is an interesting illustration of this type of S-GBR. In early 2007, a 54-year old woman came for the fixed rehabilitation of her left posterior mandible. The second premolar and 2 molars were missing, and the last extraction was done 3 years before, after a history of endodontic

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treatment and fracture of the treated teeth. She was wearing a removable denture, and the alveolar bone crest was resorbed and thin. The patient was non-smoker and presented no significant general health problems.

After anesthesia, the surgical site was opened **(Figure 3A)** with full-thickness flaps and it confirmed the dimension of the crest observed on the presurgical radiographs, i.e. 2mm in width in the crestal area, and 12mm high between the top of the crest and mandibular nerve. The bone wall was thin and almost perpendicular with the expected natural occlusion curve. This case was therefore a classical problem of reconstruction of crestal bone width. The buccal face of the crest was first activated with 10 small drills done with a surgical round bur, in order to provoke some bleeding for endosseous stimulation. Then five screws for osteosynthesis (1.5mm in diameter, 8mm long, special kit for implantology, Synthes GmbH, Zuchwil, Switzerland) were placed on this buccal face of the crest with a 90 degrees angle to the crest **(Figure 3B)**, in order to maintain the space for the grafted area laterally to this face of the thin alveolar ridge.

The space created between these screws was then filled with a bovine bone substitute (now marketed as CompactBone B, Dentegris GmbH, Duisburg, Germany) using a granulation of 0.5 to 1mm diameter per bone particle. The bone material was placed up to the head of the screws, and the whole area was then covered with a non-resorbable membrane in Teflon (TefGen membrane, Lifecore Biomedical, Chaska, MN, USA) which was adjusted to the surgical site with scissors **(Figure 3C)**. This non-resorbable barrier was placed to isolate and protect the graft from the gingival tissue, and was finally covered with a resorbable collagen membrane made from porcine pericardial tissue (now marketed as BoneProtect Membrane, Dentegris GmbH, Duisburg, Germany) in order to help gingival healing and protect the surgical site from eventual gingival dehiscence **(Figure 3D)**. This membrane was hydrophilic and quickly soaked with blood, what allowed it to remain well in place. Her resorption time was evaluated between 3 to 4 months. Periosteal incisions on the flaps were performed in order to promote a tension-free closure of the flaps, and the surgical site was sutured with non-resorbable sutures (silk 5.0, Hu-Friedy, Chicago, IL, USA). Sutures were removed after 6 days.

Seven months after the first surgery, the grafted area was healed and presented a strong gingival tissue **(Figure 4A)**. The site was reopened, and we observed a quite dense bone (D2 to D3) and no visible resorption around the osteosynthesis screws that were maintaining the space **(Figure 4B).** The 5 screws were removed carefully and the bone holes were bleeding, showing the proper biological integration of the grafted material **(Figure 4C)**. Two implants were then placed after careful drilling (TSIII implants, OssTem, Busan, South Korea; 3.5mm and 4.5mm in diameter, 11.5mm long)**(Figure 4D)**. The collars of the implants were not completely covered on the buccal face **(Figure 4E)**. During the drilling for the implant placement, the bone of the wells was collected and used as grafting material on the collar threads and the head of the implants. A final layer of bovine bone material (CompactBone B) was placed on the surgical site, in order to reinforce the previously grafted volume **(Figure 4F)**; the whole area was covered with 4 layers of L-PRF (marketed as Intra-Spin system and the Xpression preparation kit, Intra-Lock, Boca-Raton, FL, USA) in order to protect the grafted volume, to help the gingival healing, to avoid soft tissue dehiscence and to improve the maturation of the gingival tissue around the implants **(Figure 4G)**.

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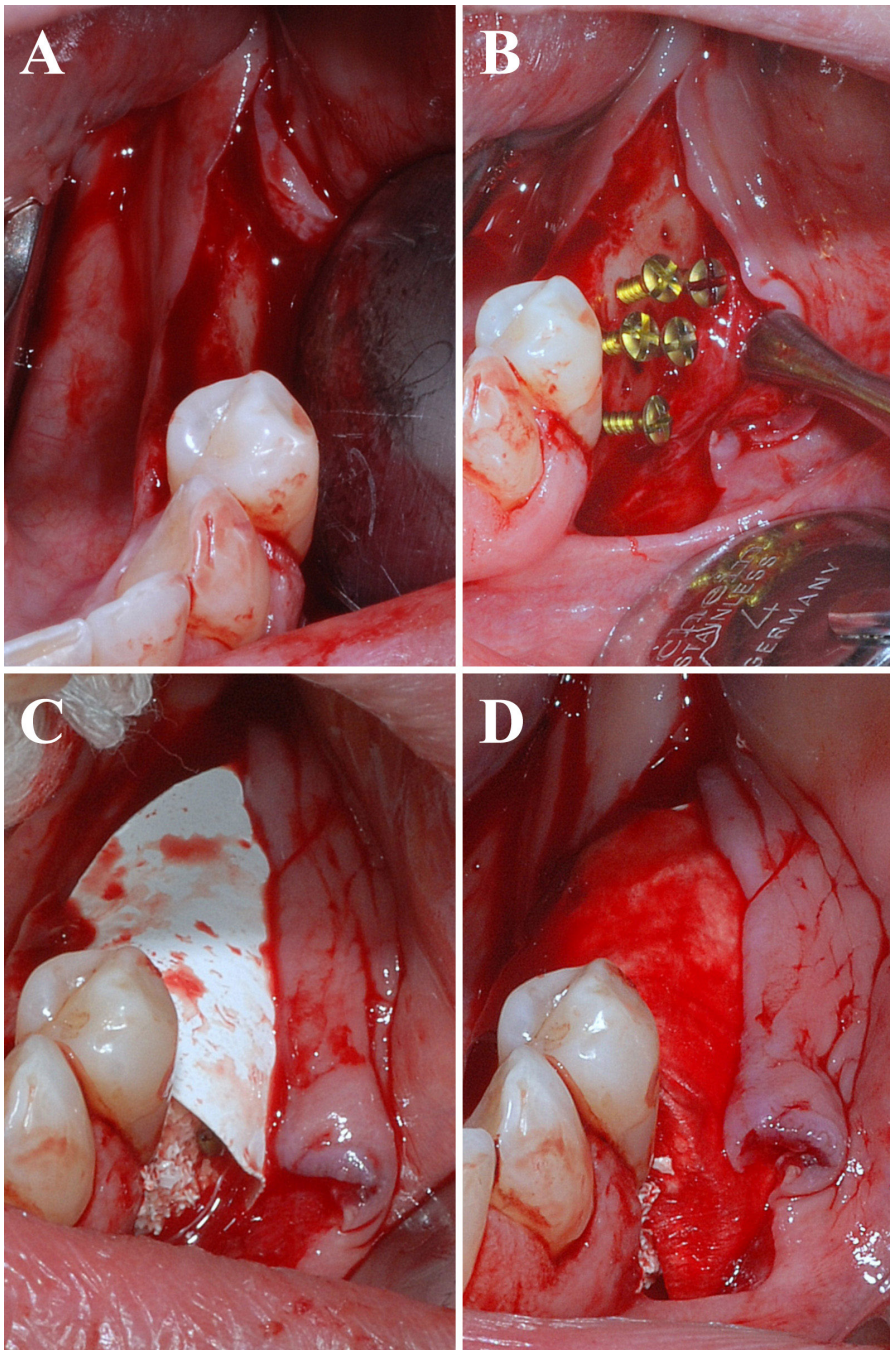

Figure 3. Screw-Guided Bone Regeneration (S-GBR) surgery in the severely resorbed posterior mandible. (A) The residual alveolar ridge was very narrow and could not be implanted directly. **(B)** Five screws for osteosynthesis were placed on the buccal face of the ridge, with a 90 degrees angle to the crest. **(C)** The space created by these screws was then filled with a bovine bone substitute, and the whole area was then covered with a non-resorbable membrane in Teflon, carefully adjusted to the surgical site. **(D)** This barrier was finally covered with a resorbable collagen membrane, to help gingival healing and protect the surgical site. This membrane absorbed blood quickly, and the site was sutured.

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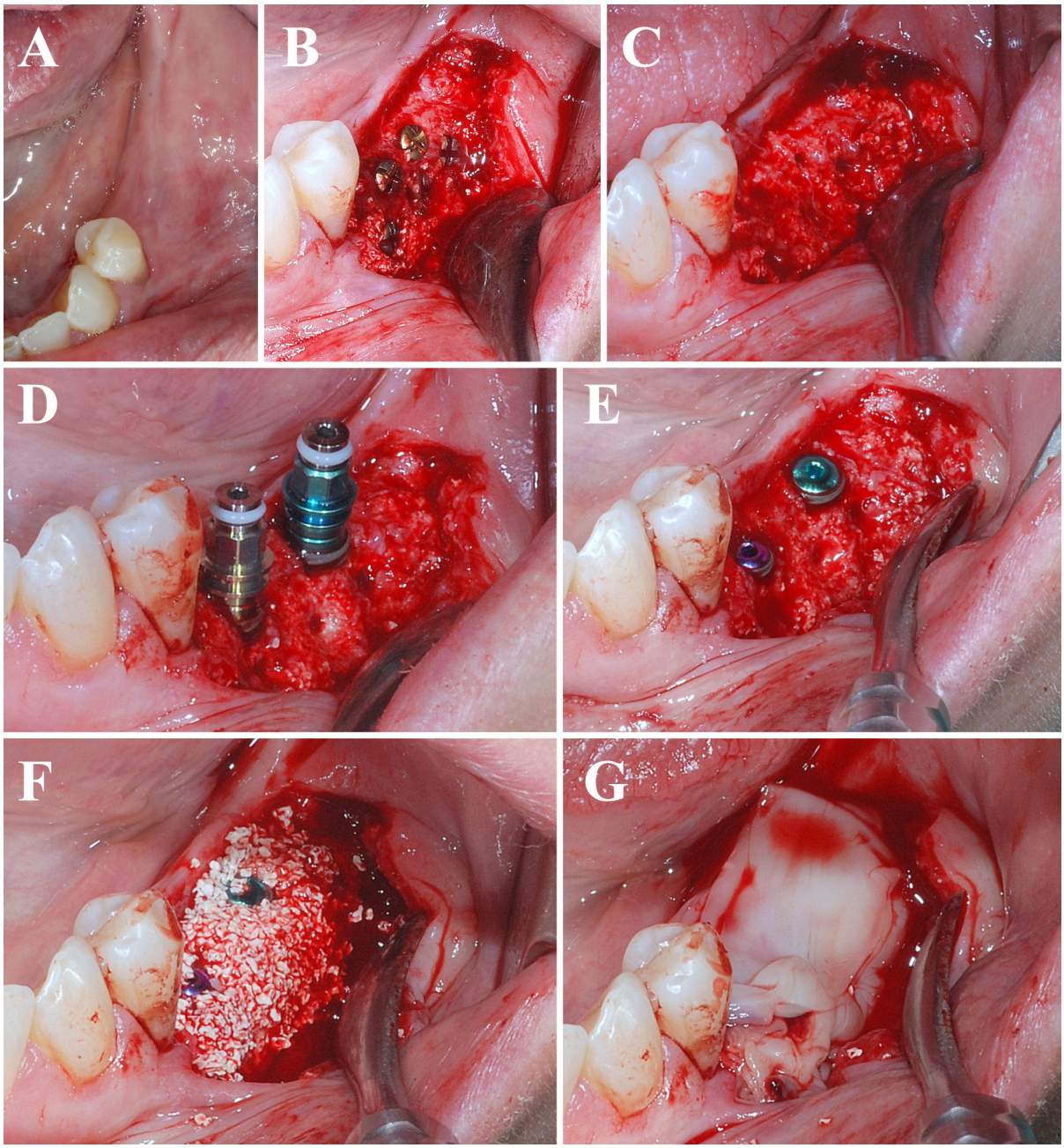

Figure 4. Implant placement and second phase of the S-GBR strategy in the severely resorbed posterior mandible. (A) Seven months after the first surgery, a strong gingival tissue was observed on the healed grafted area. **(B)** The site was reopened and the grafted volume seemed stable and strong around the screws. **(C)** The screws were removed carefully, and we observed some light bleeding from the screw holes. **(D)** Two implants were placed. **(E)** Cover screws were placed and the collars of implants were not completely immerged in bone. **(F)** A bovine bone material graft was added to regenerate more bone on the alveolar ridge around the implants. **(G)** The site was then covered with 4 layers of L-PRF membranes to protect the grafted volume and to help the gingival healing and maturation.

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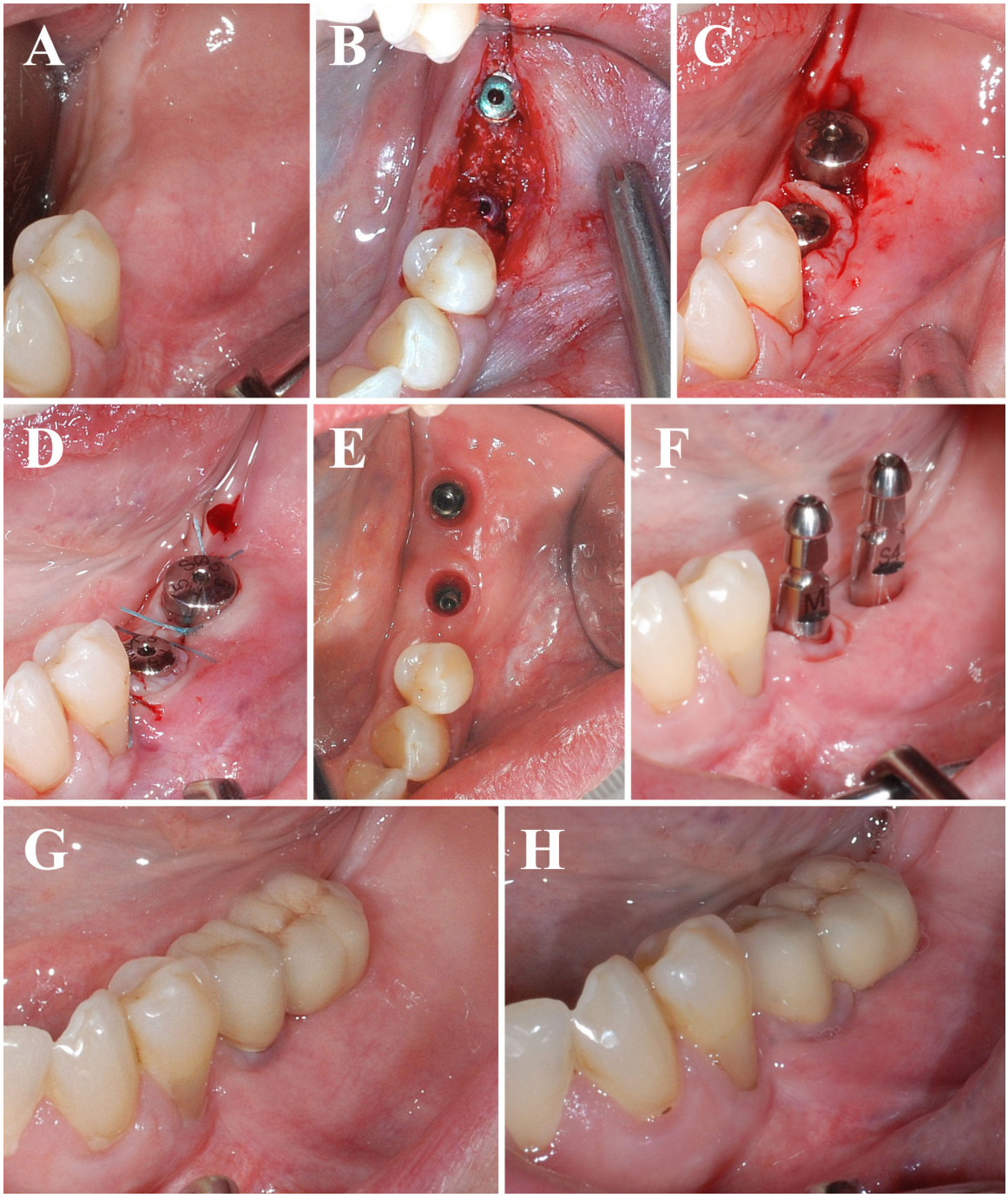

Figure 5. Prosthetic phase of the S-GBR strategy in the severely resorbed posterior mandible. (A) Eight weeks after the implantation, the gingival tissue was healed and mature with the effects of L-PRF, and the implants were ready for loading. **(B)** Implants were uncovered using a simple incision. **(C)** Implants were connected to trans-gingival healing screws, and a semi-lunar flap was placed to recreate a papilla. **(D)** The site was sutured. **(E)** After 2 weeks of healing, the gingiva was healed and the trans-gingival screws were removed. **(F)** Impression abutments were placed and impression was performed. **(G)** Two weeks later, the implant-supported bridge was placed. **(H)** After a careful 5-year follow-up, the rehabilitation was clearly functional and esthetic, and no bone loss was observed around the implants. We can also observe an increase of the gingival peri-implant covering, probably related to the maturation induced by the use of L-PRF.

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Eight weeks after the second surgery, the gingival tissue was healed and the implants were considered ready for loading **(Figure 5A)**. The implanted area was opened with a simple incision **(Figure 5B)**, and the implants were connected to trans-gingival healing screws. Using a semi-lunar incision, a piece of gingiva was placed between the 2 implants **(Figure 5C)** in order to recreate a papilla **[65]**, and the site was sutured with non-resorbable 5.0 silk sutures (Hu-Friedy, Chicago, IL, USA)**(Figure 5D)**. Sutures were removed after 5 days. After 2 weeks of healing, the gingival tissue was healed and the trans-gingival screws were removed **(Figure 5E)**. Impression abutments were placed and the impression was taken **(Figure 5F)**. Two weeks later, the final implant-supported ceramic-metallic bridge was placed **(Figure 5G)**. The patient was then followed up each year with clinical probing and radiographs. Five years after the end of the treatment, the rehabilitation was still functional and esthetic, and no resorption was observed around the implants **(Figure 5H)**. It was also observed that the gingival tissue maturation improved year after year, probably induced by the several layers of L-PRF that were used during this therapeutic strategy.

This clinical case presents an early approach of the S-GBR using L-PRF. In this case, the use of the L-PRF was very limited in comparison to all the current potential applications available. However, the treatment of this complex case remains a good illustration of the extension of the S-GBR concept to the most difficult clinical situations, and this approach can open a new Frontier beyond the traditional GBR limitations.

5. Conclusion: GBR, S-GBR or NBR?

This first article illustrates the history of GBR and how the concept of S-GBR arose with its particularities. The S-GBR can be defined as a guided bone regeneration strategy where the bone compartment is protected by a barrier and by screws (osteosynthesis screws and/or screw implants), which serve as strong space maintainers and regenerative pillars. This approach offers new opportunities of treatment, particularly in the severely resorbed posterior mandible.

However, if the use of screws to guide the regeneration is an important parameter, the combination of L-PRF and bone materials opened a new conceptual path. It was advocated that the use of L-PRF with adapted bone substitutes can promote a very physiological bone reconstruction, and this version of the GBR was already termed Natural Bone Regeneration (NBR)**[35,59]**. NBR and S-GBR are in fact 2 different concepts that need to be associated. The debate is opened and will take several years to be fully clarified and illustrated with the feedback of experience. As a conclusion, terminology is a complex matter, but it should not be neglected as it points out the conceptual differences or similarities between various clinical approaches. Understanding the nuances of techniques remains an important step to improve and develop new techniques.

Disclosure of interests

The authors have no conflict of interest to report.

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Clinical case letter

The concept of Screw-Guided Bone Regeneration (S-GBR). Part 2: S-GBR in the severely resorbed preimplant posterior mandible using bone xenograft and Leukocyte- and Platelet-Rich Fibrin (L-PRF): a 5-year follow-up

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1. Introduction

The treatment of the severely resorbed posterior mandible is always a challenge. Even if many therapeutic options have been tested with success using various forms of distractions **[1]**, osteotomies **[2,3]** or Guided Bone Regeneration (GBR)**[4]**, they all remain difficult to use and there is no consensus. It remains difficult to obtain a proper integration of a regenerated bone volume on the very cortical bone of the mandible body.

A specific form of GBR was developed using screws as space maintainers and regenerative pillars for the protection and bone growth orientation of the bone regenerative compartment, and was termed Screw-Guided Bone Regeneration (S-GBR). This approach appeared particularly adapted to the posterior mandible sites, as the screws are efficient support and protection for the bone regenerative chamber against the various mechanical constraints. This form of GBR can be associated with non-resorbable or resorbable membranes and various combinations of bone materials **[5]**, but the use of Leukocyte- and Platelet-Rich Fibrin (L-PRF, Intra-Spin system, Intra-Lock, Boca-Raton, FL, USA)**[6]** membranes became a very logical addition to any S-GBR protocol **[7,8]**.

L-PRF is an optimized blood clot concentrating most of the platelets and half of the leukocytes from a 10mL blood sample **[6,9]**, and promotes healing through the release of growth factors **[10]**. After compression in a specific box (L-PRF Xpression kit, Intra-Lock, Boca-Raton, FL, USA), we can obtain easily large numbers of these membranes **[11]**. The fibrin membrane is particularly helpful to protect a surgical site and promote quick wound closure **[7,8,12]**, and is therefore an interesting addition to S-GBR strategies were the risk of soft tissue dehiscence and bone chamber contamination remains the main threat to the treatment outcome.

In this article, we are describing for the first time a classical S-GBR protocol we have been using in daily practice for 6 years, were the screws are associated with a bone xenograft, a collagen membrane, some allograft and L-PRF membranes.

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2. Materials/methods and results

In 2007, this 67 years old woman came to the implant consultation. Her mandibular right second premolar and 3 molars were absent and all extracted more than 6 years ago. The patient was wearing a partial denture since 6 years and was expecting a fixed prosthetic rehabilitation of this area. We observed a strong resorption of the alveolar ridge, with a significant piece of free gingiva on the top of the slim residual alveolar crest **(Figures 1A, 1B)**. This patient was in good health and a moderate smoker (5 cigarettes per day). The remaining right first premolar was moving with a terminal mobility.

During the first surgery, we started by extracting the mobile first premolar and the residual alveolus was carefully cleaned using hand instruments and round bur. The residual alveolar bone crest appeared very resorbed and slim **(Figure 1C)**. In order to place implants in an adequate functional and esthetic position, the bone ridge should be regenerated both in width and in height.

As a first step to prepare the bone regenerative compartment, we drilled 10 holes in the cortical buccal wall of the residual crest, in order to provoke light bleeding following the endosseous stimulation principles. Five osteosynthesis screws (1.5mm in diameter, 8mm long, special kit for implantology, Synthes GmbH, Zuchwil, Switzerland) were then placed on the same buccal wall, to serve as tent pegs and space maintainers for the bone regenerative compartment and as supporting pillars for the grafted material **(Figure 1D)**. The position of the screws was important, as the position of the head of the screws would define the future position of the regenerated alveolar ridge and the space available for the implant positioning. In this case, we wished bone regeneration in width and in height following the expected occlusal line of the future prosthetic rehabilitation; therefore the osteosynthesis screws were placed in line with a 45 degrees from the expected horizontal occlusal face of the regenerated bone ridge. The position line was thought to support the bone grafting material and the bone growth in lateral and vertical position, and to build up the buccal/occlusal corner of the regenerated bone ridge at least up to the level of the initial residual crest.

In this technique, the choice of the bone material and of the GBR barrier membrane was very important and their combination was a critical parameter. In this case, we decided to combine a naturally cross-linked collagen membrane with a relatively short resorption time of 8 to 12 weeks (now marketed as BoneProtect Guide, Dentegris GmbH, Duisburg, Germany). This medium-term barrier was placed in position first **(Figure 1E)**. Then the bone regenerative compartment between the osteosynthesis screws was filled with a special mixed bone material prepared with half of allogeneic bone material (Tutoplast Spongiosa, Tutogen Medical GmbH, Neunkirchen am Brand, Germany) and half of a bovine bone substitute (now marketed as CompactBone B, Dentegris GmbH, Duisburg, Germany) using a granulation of 0.5 to 1mm diameter per bone particle **(Figure 1F)**. Finally, the regenerative chamber and bone materials were covered with 4 layers of L-PRF membranes (marketed as Intra-Spin system and the Xpression preparation kit, Intra-Lock, Boca-Raton, FL, USA)**(Figure 1G)**, and the collagen membrane was repositioned over the site. Periosteal incisions were performed on the flaps in order to promote a tension-free closure of the flaps. The surgical site was sutured with non-resorbable sutures (silk 4.0, Hu-Friedy, Chicago, IL, USA)**(Figure 2A)**. Sutures were removed after 6 days. The post-surgical follow-up was uneventful.

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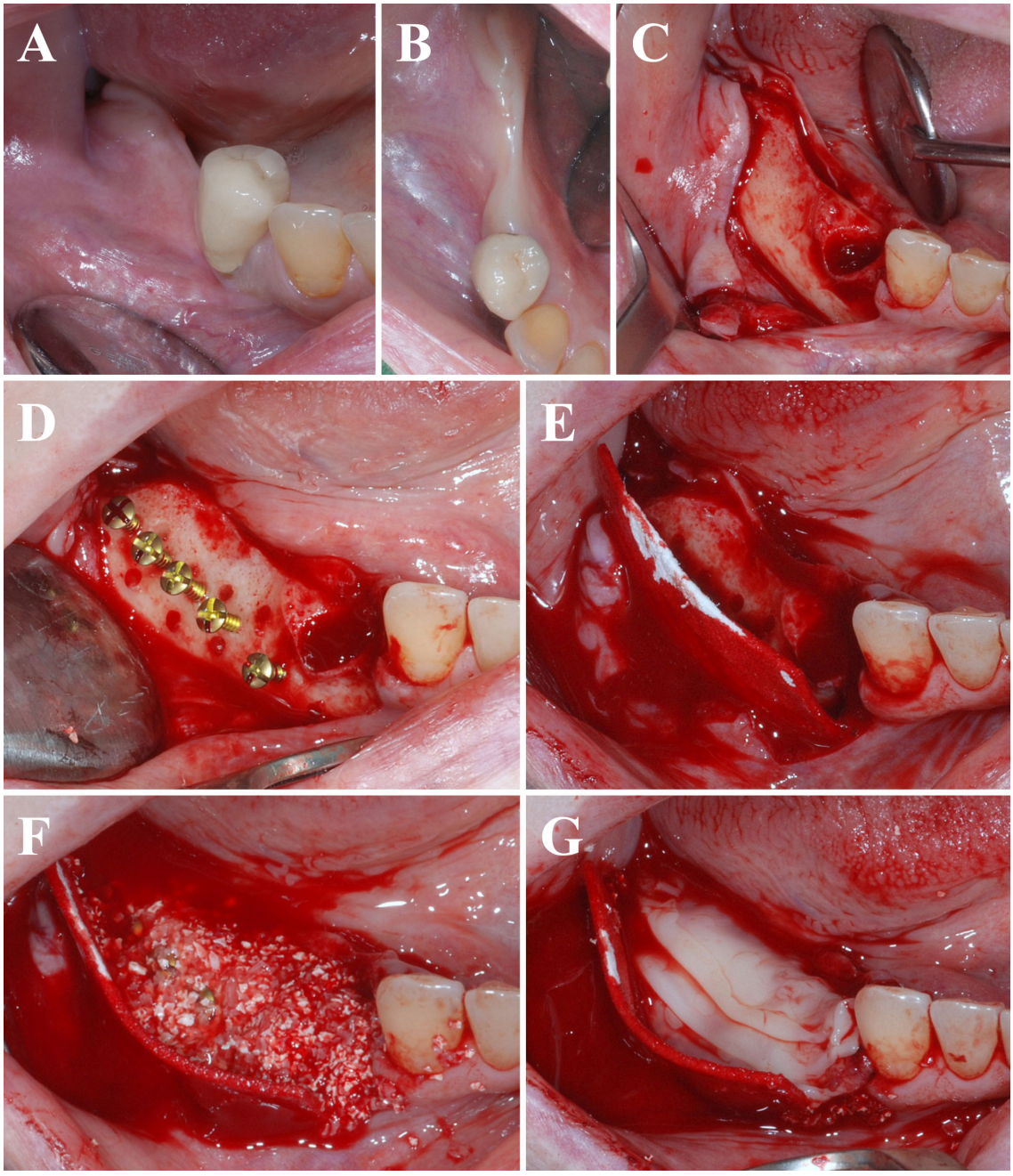

Figure 1. S-GBR surgery in the severely resorbed posterior mandible. (A, B) Initial situation. We observed a thin crest with a free piece of gingiva on the top. **(C)** The surgical site was opened revealing a severely resorbed residual ridge, and the residual mobile premolar was extracted. The alveolus was carefully curetted. **(D)** Ten holes of endosseous stimulation were done to prepare the bone compartment. Five osteosynthesis screws were placed in line in adequate position, with a 45 degrees angle from the expected occlusal plan. **(E)** A collagen membrane was placed to delimit the future bone regeneration compartment. **(F)** The space between and above the screws was filled with a mixed bone material (50% bovine xenograft, 50% allograft). **(G)** The regeneration compartment was covered with 4 layers of L-PRF membranes, and the collagen membrane was then replaced on it.

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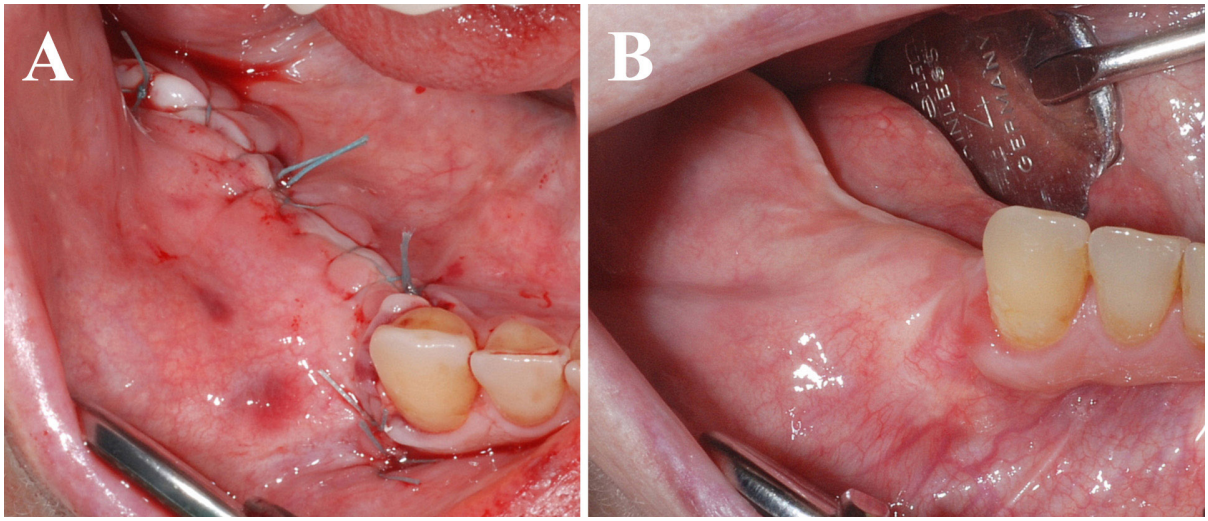

Figure 2. Follow-up of the S-GBR surgery in the severely resorbed posterior mandible. (A) Sutures were done tension-free thanks to periosteal incisions on the flaps. **(B)** Four months after the surgery, the gingival tissue was healed, keratinized and adherent on a wide regenerated alveolar ridge.

Four months after the initial regeneration surgery, the gingival tissue appeared healed and mature **(Figure 2B)**. The regenerated alveolar crest had a very different aspect and appeared wide and strong, and the radiographic follow-up did not show any anomaly.

During the second surgical step, the flaps were raised again to reenter the site. The bone aspect was a bit irregular on the external layer, lightly bleeding and compact with a D2-D3 density **(Figure 3A)**. The heads of the osteosynthesis screws appeared clearly. The 5 screws were removed carefully, and light bleeding could be observed from the holes **(Figure 3B)**. Two implant osteotomies were performed in this dense bone and the holes were both bleeding and apparently homogeneous **(Figure 3C)**. Two implants were then placed (Xive, Dentsply Implants, Mannheim, Germany), respectively 3.8mm x 11mm and 4.5mm x 11mm **(Figure 3D)**. Some autologous bone from the implant osteotomy drilling was collected and added around the collars of the implants to reinforce this important area. The whole regenerated area was covered with a final layer of bovine bone substitute (now marketed as CompactBone B, Dentegris GmbH, Duisburg, Germany), in order to increase and stabilize the regenerated bone volume **(Figure 3E)**. Finally, the whole area was covered with 4 layers of L-PRF membranes (marketed as Intra-Spin system and the Xpression preparation kit, Intra-Lock, Boca-Raton, FL, USA)**(Figure 3F)**, in order to maintain the supplementary grafting material and to promote the healing and maturation of the gingival tissue.

Three months after this second surgery, the trans-gingival healing screws were connected. After healing, the prosthetic abutments were placed **(Figure 4A)** and the final prosthesis was added 2 weeks later. The total time to do this rehabilitation was therefore around 8 months. The clinical and radiographic follow-up was done each 6 months during the first 2 years and then each year. Five years after treatment, the rehabilitation appeared stable and no bone loss was noticed **(Figure 4B)**.

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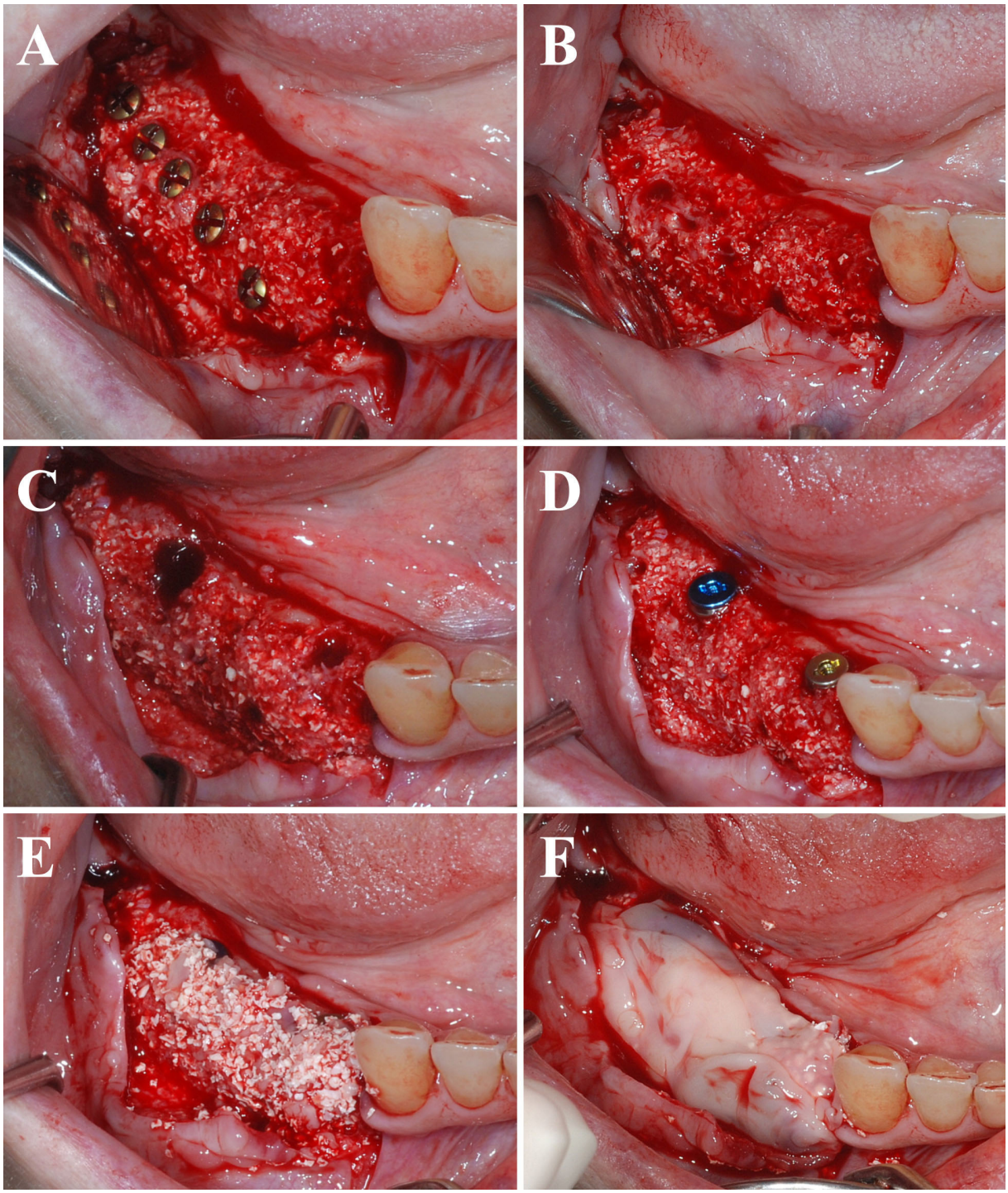

Figure 3. Implantation phase, four months after S-GBR surgery in the severely resorbed posterior mandible. (A) Four months after S-GBR, the surgical site was reopened, revealing a dense, lightly bleeding and irregular external aspect of the regenerated volumes around the screws. **(B)** Screws were removed, and a light bleeding appeared from the holes. **(C)** Implant osteotomies were done. **(D)** Two implants were placed. **(E)** Autologous bone from drilling was placed around the implant collars and then covered with a supplementary layer of bovine xenograft bone material. **(F)** Four layers of L-PRF membranes were placed all over the surgical site, to maintain the grafted material and to stimulate soft tissue healing and maturation. Then the site was sutured tension-free.

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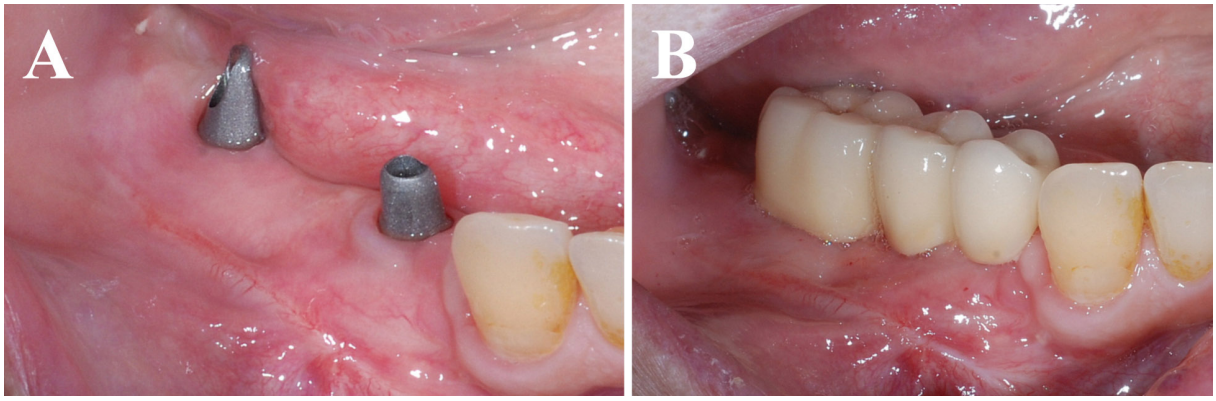

Figure 4. Prosthetic phase and follow-up. (A) Three months after implantation, trans-gingival screws were placed, and abutments were connected 2 weeks later **(B)** Five years after the end of treatment, the rehabilitation appeared stable and no bone loss was noticed in the radiographic and clinical follow-up.

3. Discussion

This case is a description of a traditional approach to S-GBR. The use of screws is not very difficult in theory and the bone regeneration appeared to be stable, but the way to prepare the regeneration chamber must be handle with care, particularly the endosseous stimulation, the position of the screws and the flap closure. However, the real question always remains what kind of materials and membranes to associate – and how to associate them – to get the best clinical results.

In the early phase of this technique, as described in the part 1 of this article series, we were mostly using xenograft. This material was mostly mineral with a very slow remodeling time and weak integration **[13]**, what required to combine it with a collagen resorbable membrane and a Teflon non-resorbable membrane. In our experience, this strategy worked well, but longer healing times were needed to have a regenerated bone for proper implantation (7 months for regeneration).

In the case described in this article, the procedure was simplified thanks to a better selection of materials. The bone grafting material was a mix of allograft and xenograft: the allograft integrated quicker on the surgical site, while the xenograft was more stable on the long-term **[14]**. No non-resorbable membrane was needed. We still used a collagen membrane because of the presence of the mineral xenograft material **[13]**. We used L-PRF membranes everywhere to improve bone integration, gingival healing and maturation and to secure the surgical site **[7,8]**. The exact properties of the L-PRF membranes as GBR barrier are debated **[15]** and largely dependent on the way it is used, but this material anyway offers a great opportunity to improve soft tissue healing and to avoid gingival dehiscence above the bone regeneration chambers **[7,8]**. With this method the surgery was easier and the required time for bone regeneration did not exceed 4 months. More important, the bone regeneration appeared more homogeneous clinically, even if we are lacking proper scientific evaluation.

As a conclusion, in our experience, the S-GBR strategy is an efficient approach for the treatment of the severely resorbed mandible. L-PRF appeared to be a strong element of surgical simplification, reduction of gingival dehiscence risks and improvement of soft tissue

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maturation. The choice of the adequate combination of bone materials and barriers remains debatable, and requires further scientific evaluation on large series.

Disclosure of interests

The authors have no conflict of interest to report.

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Clinical case letter

The concept of Screw-Guided Bone Regeneration (S-GBR). Part 3: Fast Screw-Guided Bone Regeneration (FS-GBR) in the severely resorbed preimplant posterior mandible using allograft and Leukocyte- and Platelet-Rich Fibrin (L-PRF): a 4-year follow-up

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1. Introduction

The rehabilitation of the severely resorbed posterior mandible remains a challenge. Even if many techniques of bone regeneration were tested with success in this area, they remain difficult surgeries and no consensus or standard have been raised yet **[1]**. Because of the thick cortical bone of the mandible body, the alveolar bone regeneration or integration of a grafting material is often compromised. Moreover, the management of a regenerative compartment in this area is always difficult due to mechanical constraints and risk of soft tissue dehiscence.

In this series of article, we developed and illustrated the concept of Screw-Guided Bone Regeneration (S-GBR), with excellent results in the posterior mandible. In this form of GBR, the barrier between the bone and gingival compartment is supported and protected through the presence of screws, serving both as tent pegs to maintain the regenerative chamber space and as bone growth pillars. Many combinations of bone materials and membranes are possible to get adequate results with various healing times **[2,3]**, but the use of Leukocyte- and Platelet-Rich Fibrin (L-PRF)**[4]** membranes as interposition, healing and maturation material became a common standard for us **[5,6]**. L-PRF (Intra-Spin system and Xpression kit, Intra-Lock, Boca-Raton, FL, USA) is an optimized blood clot or membrane, which concentrates most of the platelets and half of the leukocytes of a blood sample **[7,8]**. Through the release of growth factors and the effect of fibrin **[9,10]**, this material promotes - among other effects - quick soft tissue healing and maturation **[5]** and is considered as a form of barrier for Guided Bone Regeneration **[11]**.

In this article, we describe a modification of the S-GBR protocol termed Fast Screw-Guided Bone Regeneration (FS-GBR), where the severely resorbed posterior mandible was treated mostly with screws, allograft material and L-PRF membranes in order to reduce significantly the healing and regeneration times of the alveolar ridges.

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2. Materials/methods and results

In early 2009, a 72 years old woman came to the implant consultation with mandibular posterior bilateral edentulous ridges. On both mandibular sides, all premolars and molars were absent since more than 10 years, except the left residual wisdom tooth, which seemed conservable **(Figure 1A)**. The patient was non smoker and in good general health. She was wearing a removable denture since 10 years and wished a fixed prosthetic rehabilitation. The clinical and radiographic examinations showed severely resorbed residual alveolar ridges on both sides. The residual bone height was adequate but the crests were much too thin to place an implant directly. It was therefore decided to perform a S-GBR surgery on both sides, using a specific protocol to accelerate bone regeneration.

During the initial surgery, the flaps were raised and the alveolar ridges appeared very thin as expected **(Figure 1B)**. In order to place implants in proper functional and esthetic position, it was needed to regenerate a bone volume both in width and in height. The regeneration chamber was prepared first by the drilling of 10 holes within the buccal cortical plate of the alveolar wall, following the principles of the endosseous stimulation **(Figure 1C)**. Then 4 osteosynthesis screws (1.5mm in diameter, 8mm long, special kit for implantology, Synthes GmbH, Zuchwil, Switzerland) were placed in line on the same buccal face of the alveolar ridge, in order to serve as space maintainers and regenerative pillars for the bone regeneration compartment **(Figure 1D)**. Care was taken to place them in adequate position so that the heads of the screws constitute the corner between the occlusal face and buccal face of the expected regenerated alveolar ridge. In this therapeutic strategy, the screws in fact delimited the final position of the GBR barriers and the periosteum, and therefore fixed the line of the future alveolar wall. They also must maintain and support the grafting material within the regenerative compartment and must therefore be relatively close from each other. In this case, regeneration in width and height was needed to place the implants in a position compatible with the occlusal prosthetic line and function. The screws were placed in line with a 45 degrees angle from the expected horizontal occlusal plan of the prosthetic rehabilitations.

In this case of FS-GBR, the bone regenerative compartment was only filled with allogeneic bone material (Tutoplast Spongiosa, Tutogen Medical GmbH, Neunkirchen am Brand, Germany), that was placed carefully between and above the screws **(Figure 1E)**. Then the surgical site was covered with 2 layers of L-PRF membranes (marketed as Intra-Spin system and the Xpression preparation kit, Intra-Lock, Boca-Raton, FL, USA)**(Figure 1F)**. These membranes were the only barriers that were used in this technique, and served both as GBR barriers for the bone regenerative compartment and as healing material for the stimulation of gingival flap healing and maturation. Periosteal incisions were done on the internal face of the flaps in order to promote a tension-free closure of the flaps, and the surgical area was sutured with non-resorbable sutures (silk 4.0, Hu-Friedy, Chicago, IL, USA). The exact same protocol was then applied during the same surgical time on the right alveolar ridge using 4 screws and the same bone materials and L-PRF **(Figures 1G, 1H)**. On both sides, the post-surgical follow-up was uneventful and sutures were removed after 6 days.

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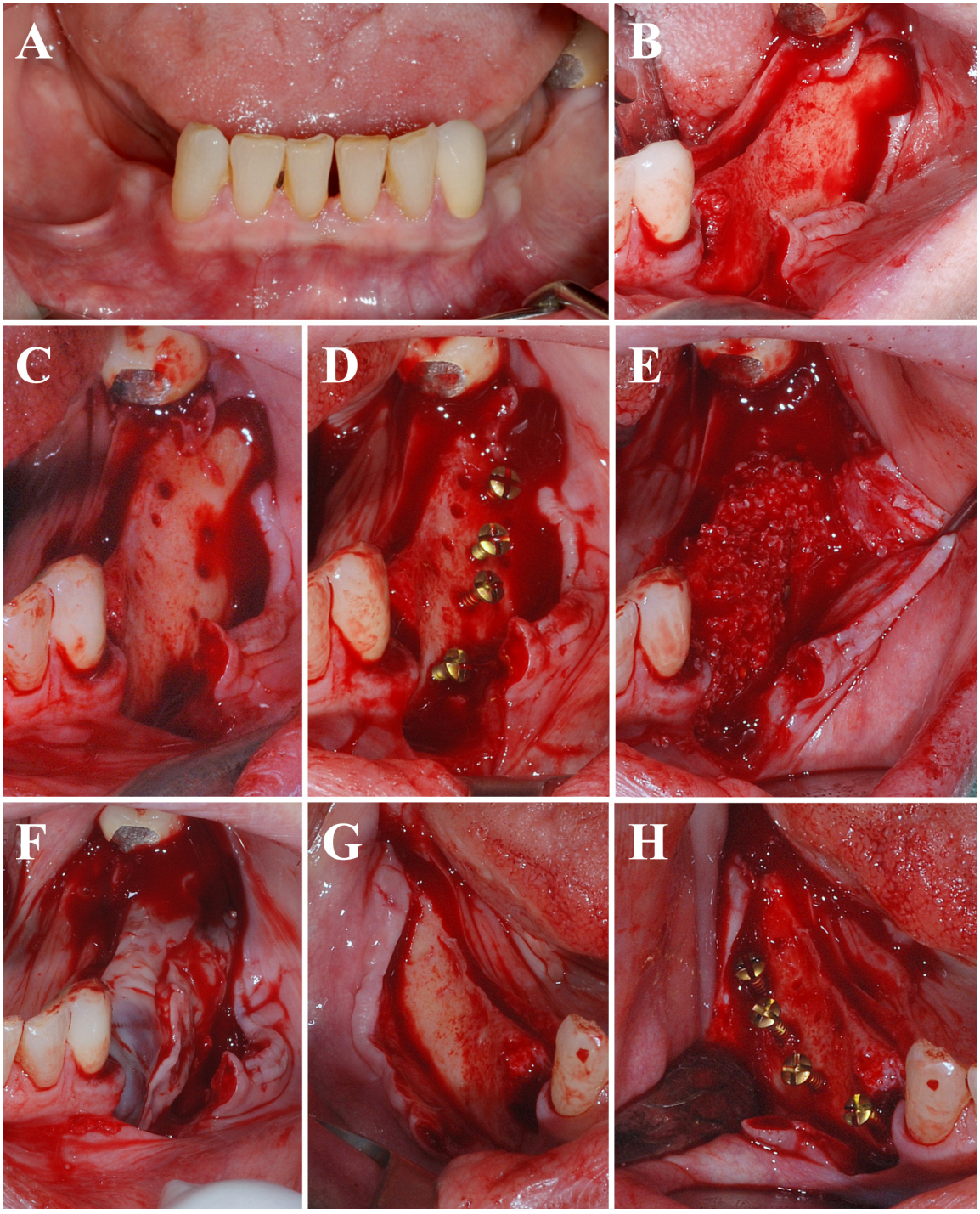

Figure 1. Bilateral FS-GBR surgery in the severely resorbed posterior mandible. (A) Initial situation. **(B)** The left surgical site was opened and revealed a severely resorbed crest. **(C)** Ten holes of endosseous stimulation were done to prepare the bone regeneration compartment. **(D)** Four osteosynthesis screws were placed in line on the residual alveolar ridge, with a 45 degrees angle from the expected occlusal plan. **(E)** The space between and above the screws was filled with an allograft bone material. **(F)** The whole surgical site was covered with 2 layers of L-PRF membranes, and then sutured tension-free after periosteal incisions on the flaps. **(G, H)** The right surgical site was similarly resorbed, and was treated exactly like the left side.

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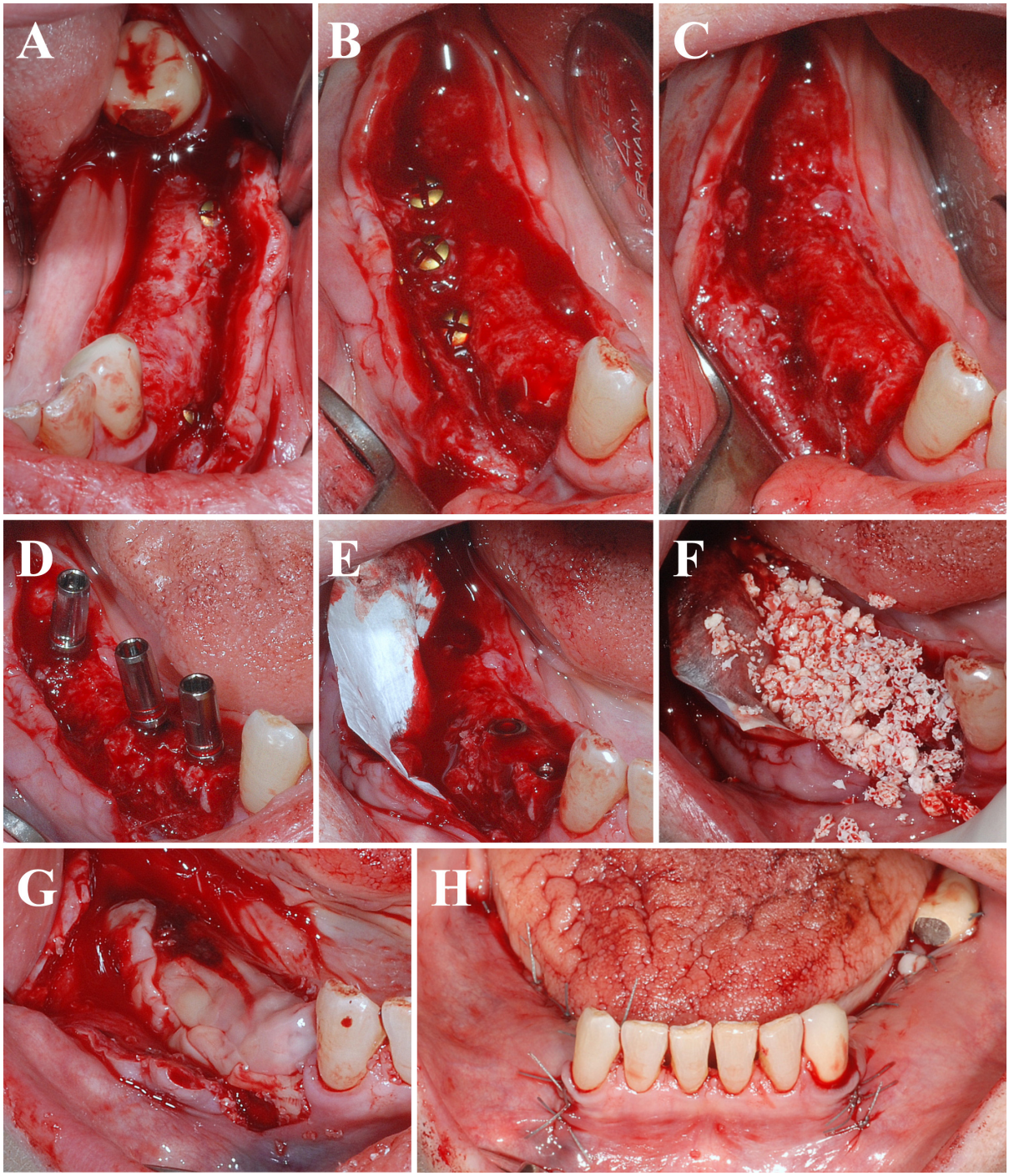

Figure 2. Implantation phase, 2 months after FS-GBR surgery in the severely resorbed posterior mandible. (A, B) Two months after FS-GBR, the surgical sites were reopened, revealing a dense, lightly bleeding and regular external aspect of the regenerated volumes. The screws were partially covered with bone. **(C)** Screws were removed, and a light bleeding appeared from the holes. **(D)** Three implants were placed on the right side, and 2 implants on the left side. **(E)** A collagen membrane was placed in position. **(F)** The whole regenerated area was covered with a supplementary layer of bovine xenograft bone material, to stabilize the regenerated alveolar ridge. **(G)** Two layers of L-PRF membranes were placed all over the surgical site, to maintain the grafted material and to stimulate soft tissue healing and maturation. **(H)** The sites were sutured tension-free using again periosteal incisions.

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Eight weeks after the bone regeneration surgery, the sites appeared well healed and were reopened. The bone volumes seemed well regenerated and homogeneous **(Figures 2A, 2B)**. The regenerated bone was dense but relatively soft (D3 quality). The osteosynthesis screws were still covered with some regenerated bone and were then removed **(Figure 2C)**. Implant osteotomies were performed carefully and the bone volume seemed compact and homogeneous during drilling. Three implants were placed on the right side **(Figure 2D)** and 2 implants of the left side (Ankylos C/X, Dentsply implants, Mannheim, Germany), all of them 11mm long and 4.5mm in diameter, except the mesial right implant (3.5mm in diameter).

After implantation, it was decided to use a combination of bovine bone and collagen membrane to help the long-term stability of the allograft material. On both sides, a resorbable collagen membrane made from porcine pericardial tissue (now marketed as BoneProtect Membrane, Dentegris GmbH, Duisburg, Germany) was placed to delimit each regenerative compartment **(Figure 2E)**. This membrane had a long-term resorption evaluated between 3 and 4 months. Then the regenerated alveolar ridges were covered with bone particulate material (now marketed as CompactBone B, Dentegris GmbH, Duisburg, Germany)**(Figure 2F)** and the collagen membranes were closed on it respectively. The surgical sites were finally covered with 2 layers of L-PRF membranes (marketed as Intra-Spin system and the Xpression preparation kit, Intra-Lock, Boca-Raton, FL, USA) on each side **(Figure 2G)**, in order to help gingival healing and maturation and to prevent eventual gingival dehiscence. Periosteal incisions were performed again on the flaps in order to suture the sites without tensions, using non-resorbable sutures (silk 4.0, Hu-Friedy, Chicago, IL, USA)**(Figure 2H)**. Sutures were removed after 6 days.

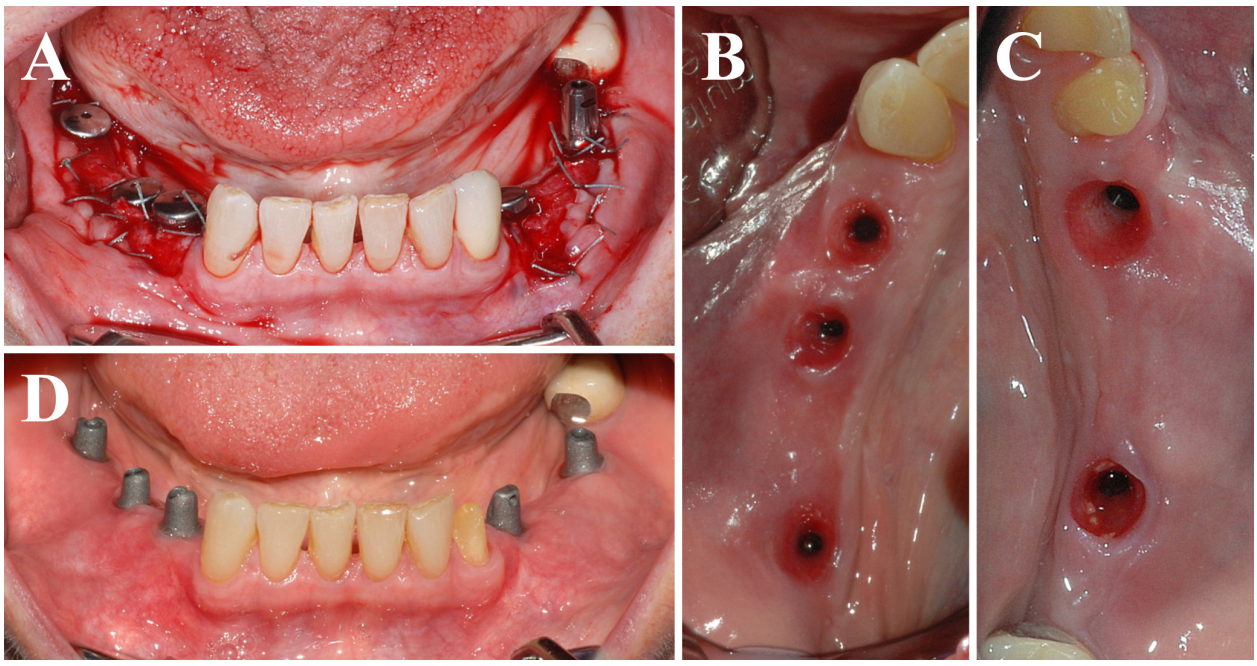

Figure 3. Prosthetic phase and follow-up. (A) Three months after implantation, trans-gingival screws were placed and the sites were sutured using split-thickness apically repositioned flap to improve the peri-implant gingival shape. **(B, C)** After 4 weeks of healing, the gingival tissue appeared healed and strong. **(D)** The implant abutments were placed.

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Three months after implantation, the sites were reopened and the grafted volumes appeared homogeneous and stable. The trans-gingival screws were connected, and the sites were sutured using a split-thickness apically repositioned flap designed to readapt the gingival peri-implant contour to the final regenerated ridges **(Figure 3A)**. After 4 weeks of healing, the peri-implant tissues appeared mature and strong **(Figures 3B, 3C)**. The impression was done and the abutments were placed **(Figure 3D)**. Two weeks later, the final implant-supported prostheses were placed **(Figure 4A)**. The total time to perform this rehabilitation was therefore around 6 months, what was a very quick treatment considering the numbers of surgical steps and the bone volumes to regenerate.

The clinical and radiographic follow-up was done each 6 months the first year and then each year. Four years after the end of the treatment **(Figure 4B)**, the rehabilitation appeared stable and functional. A residual bone resorption in thickness could be observed clinically on the regenerated alveolar ridges, but no bone loss was observed around the implant collars during this 4-year follow-up. The gingival tissue also evolved during this period and appeared thicker. It may be related to the maturation with the repetitive use of L-PRF.

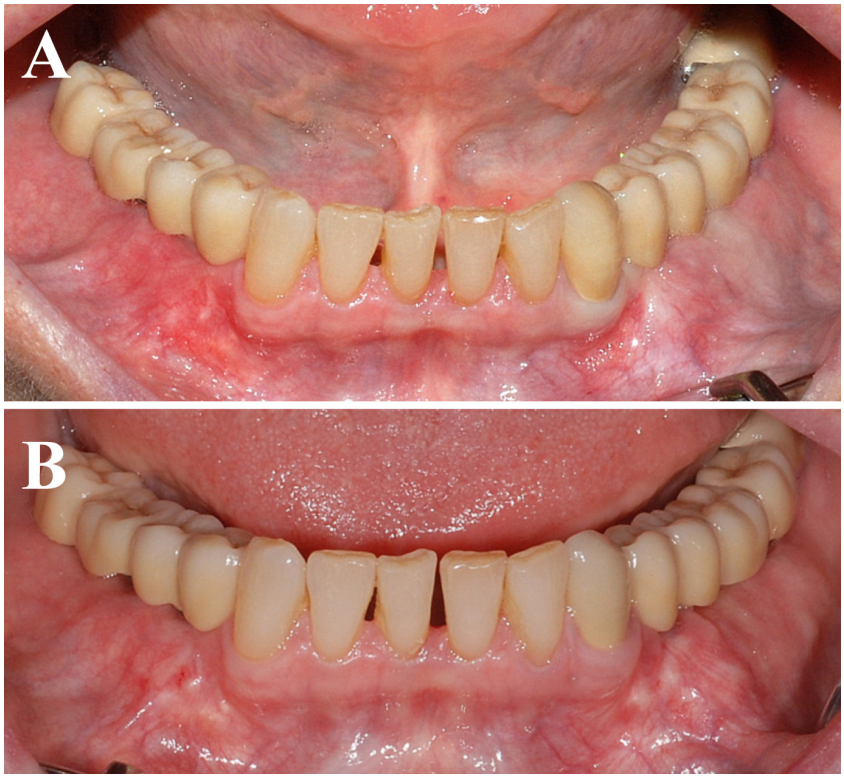

Figure 4. Follow-up. (A) The final implant-supported bridges were placed. The total time of treatment was less than 6 months. **(B)** Four years after the end of treatment, the rehabilitation appeared stable. A small resorption in thickness of the regenerated alveolar ridges can be observed, but no peri-implant bone loss was noticed in the radiographic and clinical follow-up. The gingival tissue also evolved and appeared thicker and more adherent.

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3. Discussion

As explained in the previous parts of this series of articles, the S-GBR approach requires different healing times depending on the combination of materials and membranes **[3]**, in order to obtain bone ridges ready for implantation. With bovine xenograft, collagen membrane and non-resorbable membrane, the regeneration time was of 7-8 months. With a mix of xenograft and allograft and the cover with collagen and L-PRF membranes, the regeneration time was around 4 months. In this article, only allograft and L-PRF were used **[12,13]** and the regeneration time felt to 2 months only, what is a very fast regeneration strategy, particularly in the posterior mandible.

Even if the literature is not very clear on this matter **[14]**, it is commonly known that collagenated allograft materials have a quicker bone integration than bovine xenograft, but also that allograft have tendency to resorb slowly on the long-term while bovine xenograft are very stable with time **[15]**. For this reason, both materials were mixed in the S-GBR technique we described in the part 2. In the FS-GBR approach, the regeneration surgery was done only with allograft and L-PRF in order to stabilize quickly a regenerated alveolar ridge, and some bovine xenograft (always associated with a collagen membrane)**[15]** was added during the second surgery in order to stabilize the regenerated ridge and to control or stop the resorption of the allograft material. This final cover with bovine xenograft should not be neglected, this is a key element of this therapeutic strategy for the long-term stability of the rehabilitation. However in the FS-GBR, all steps require the use of L-PRF membranes as healing and maturation material **[5,6]**.

Finally, in this case the regeneration was done with L-PRF as sole barrier above the allograft and with only 2 layers of L-PRF (in comparison to the 4 layers described in the previous articles). It raised the question if L-PRF can be used as a GBR barrier alone **[11]**, as no collagen membrane was needed in this case. From our experience and the literature **[12,13]**, L-PRF functions as a competitive barrier when associated with the adequate bone materials and clinical situations **[5,6]**. In the case of FS-GBR, the concept of association of L-PRF with some forms of allografts (already collagenated materials) gave adequate results, but it must be investigated carefully in the future to determine the best indications and relevant combinations.

Disclosure of interests

The authors have no conflict of interest to report.

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Clinical case letter

Simultaneous implantation and reconstruction of the severely resorbed posterior mandible using an early concept of Screw-Guided Bone Regeneration (S-GBR) technique: a 14-year follow-up

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1. Introduction

The use of Guided Bone Regeneration GBR techniques is already well documented in the posterior mandible **[1]**. The concept of this technique is to create a protected bone regenerative chamber above the residual alveolar ridges in order to reconstruct a natural implantable bone volume. In this technique, the bone regenerative chamber can be delimited using various kinds of membranes or barriers, and the chamber can be filled with blood clot or various bone materials (autologous, allograft, xenograft, synthetic)**[1-3]**.

The barrier can be a resorbable membrane but a classical form of GBR is requiring non-resorbable membranes such as titanium mesh **[4]** or ePTFE (expanded polytetrafluoroethylene membranes)**[5,6]**, where the regeneration compartment is well delimited and protected from mechanical constraints. The main disadvantages of the non-resorbable membranes are particularly: their complexity of use, as they require very careful modelling and positioning; and the risks related to the gingival healing, as soft tissue dehiscence is frequent and implies serious risk of membranes contamination and destruction of the regenerative chamber **[1,6]**.

Even if the relative abundance of literature on the topic can validate the concept of these techniques, there is no real consensus on their relevance in the resorbed posterior mandible in comparison to the other therapeutic options and their use remains scarce in daily practice. There is also a lack of consensus on the adequate materials and membranes to combine to get adequate results **[1,7]**.

The concept of placing implants at the time of the GBR was already advocated but considered as quite risky in case of contamination **[5,7]**. This concept was described as a GBR with simultaneous implantation, while in fact it may be considered as a real S-GBR (Screw-Guided Bone Regeneration) concept. The idea of S-GBR is that the regenerative chamber is maintained, protected and delimited on the long-term by screws – osteogenesis screws or the dental implants themselves. In the case of a GBR with non-resorbable membrane, the simultaneous implants serve as pillars for the membrane and regeneration compartment, and also as a supporting stake for the bone growth and long-term stabilization.

In this article, we illustrate this early concept of S-GBR as a case of simultaneous implantation and GBR treatment in the posterior mandible with a 14-year follow-up.

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2. Materials/methods and results

In this case, a 67-year old female came in the practice in 1998 and required a posterior rehabilitation of the lower right mandible **(Figure 1A)**. The patient was healthy and non-smoker. Her right second premolar and first molar were recently extracted (2 months earlier) due to severe periodontal disease with repetitive abscess and deep bone resorption **(Figure 1B)**. Only the second molar was conserved temporarily, as the tooth was damaged but conservable the time of the bone surgery. On the Computed Tomography CT-scanner, the alveolar bone height available above the mandibular nerve was around 6mm or lower **(Figure 1C)**. It was also noticed that the residual alveolar ridge and mandible body were quite wide.

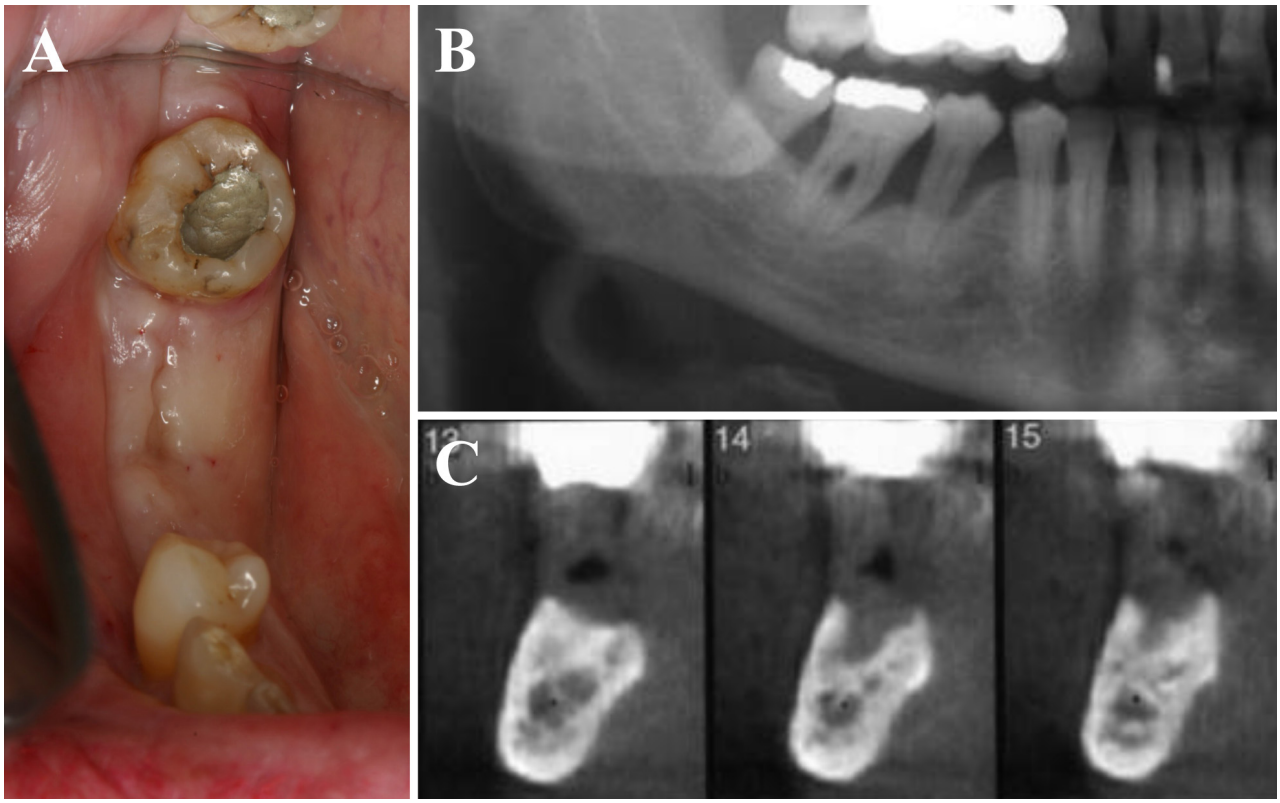

Figure 1. Initial situation. (A) The lower right first premolar and first molar were extracted 2 months earlier and the second molar was left temporarily. **(B)** The site was significantly resorbed due to severe periodontal lesions and repetitive abscess around the 2 teeth prior to their extraction **(C)** Two months after extraction, the future implant sites were not completely healed and the remaining bone heights were around 6mm or lower above the mandibular canal.

The surgical site was opened and the alveolar sockets of the previously extracted teeth were only very partially healed **(Figure 2A)**. Fibrous tissue was carefully removed around and in the sockets. Then a bone scraper was used to collect autologous bone fragments all around the surgical site **(Figure 2B)**, and to model the alveolar ridge for the fixation of the regeneration membrane, the implantation and the closure of the gingival flap above the regenerative area without excessive tractions of the soft tissues. The collected bone volume was significant **(Figure 2C)** and was stored in a surgical pot with some drops of

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physiological solution **(Figure 2C')**. Once the surgical site was adequately remodeled, 4 implants were placed (TSV, Zimmer Dental Inc., Carlsbad, CA, USA) with 3.7mm in diameter and 10mm, 11.5mm, 11.5mm and 10mm in length, from mesial to distal respectively **(Figure 2D)**. Their position and axis was selected with the idea to replace functionally 3 teeth, from the second premolar to the second molar, as the second molar was planned for extraction later. The implants were only partially screwed in the residual bone, in order to remain 1mm above the mandibular nerve, and 4mm long of the implant collars remained outside of the bony envelope and could serve as tent pegs for the regenerative chamber.

The collected autologous bone was then grafted around the implants **(Figure 2E)** and the area was then covered with a titanium mesh membrane (Jeil Medical Co., Seoul, South Korea) blocked with 2 screws **(Figure 2F)**. This membrane was adapted carefully to the site anatomy and expected future shape, and served as a physical barrier around the bone regeneration compartment and the gingiva. The barrier was also rigid enough to limit the mechanical constraints on the regenerative bone chamber. Finally, the titanium mesh was covered with a pericardium membrane (Tutogen Medical GmbH, Neunkirchen, Germany)**(Figure 2G)** in order to exclude soft tissue penetration, to reinforce the gingival healing and reduce the risk of gingival dehiscence. Periosteal incisions were performed to extend a little bit the surface of the flap and the surgical site was closed and sutured **(Figure 2H)**.

The post-surgical phase was uneventful and no dehiscence occurred. Three months after the first surgery, it was considered that the regeneration chamber was stable and successful and did not need further protection, and the second molar was extracted. Five months post-implantation and regeneration, the surgical site was fully reopened, and the titanium mesh was removed **(Figure 3A)**. The alveolar bone ridge was well regenerated and the heads of the implants were covered with a significant layer of hard regenerated bone **(Figure 3B)**. All implants were uncovered and the cover screws were removed **(Figure 3C)**. The trans-gingival screws were connected and the flap was sutured. After healing, an implant-supported ceramic metallic bridge was prepared and placed **(Figure 3D)**.

Clinical and radiographic follow-up was done after 6 months **(Figure 3E)** during the first 2 years and then each year. After 1 year, a CT scan control showed stable bone levels **(Figure 3F)**. The position of the 3 posterior implants was observed 1mm above the mandibular nerve, demonstrating how accurate the treatment planning had to be **(Figures 4A, 4A', 4A")**. 14 years after implantation, the rehabilitation was still functional and healthy **(Figure 4B)**. The expected peri-implant bone loss was barely visible after radiographic and clinical examination.

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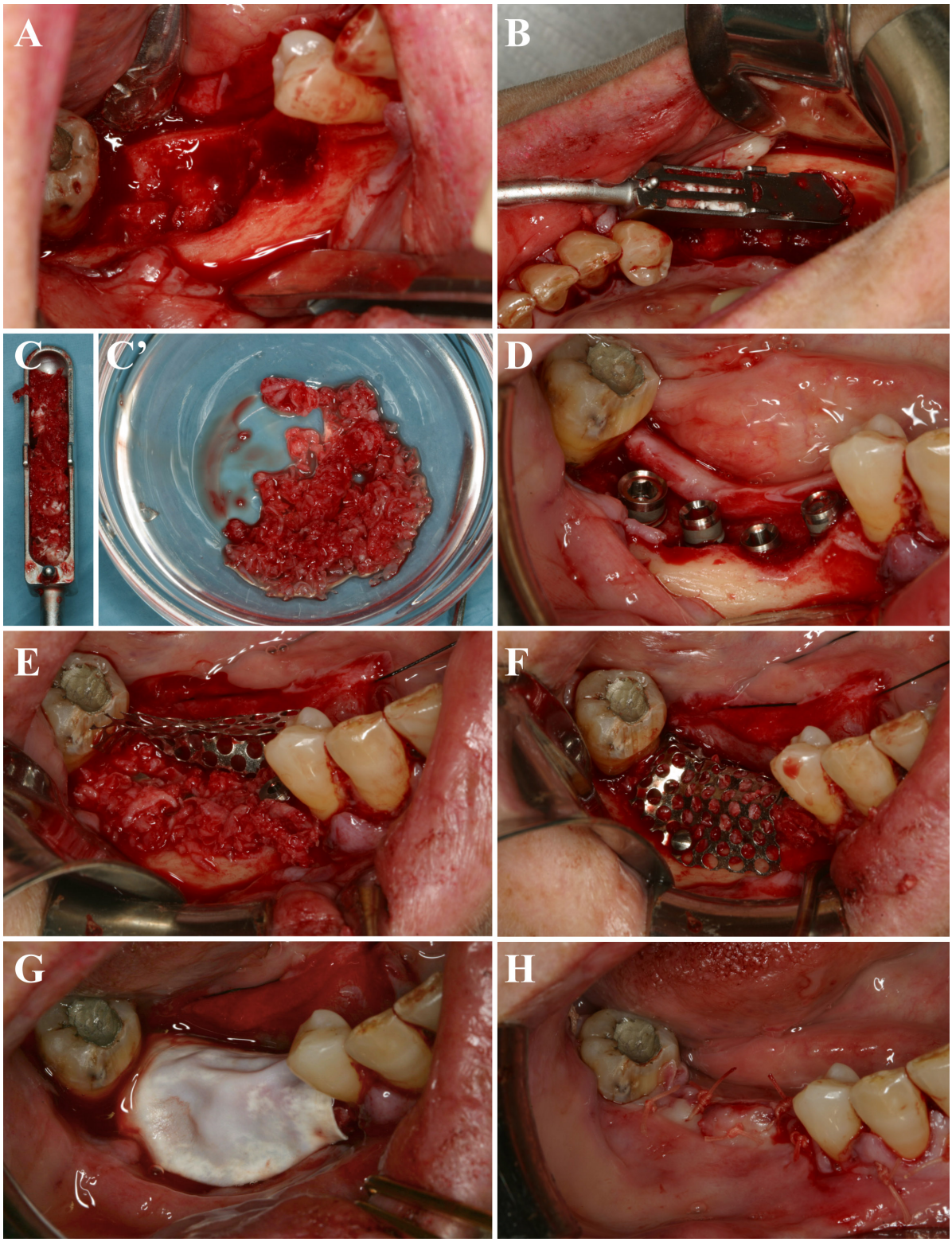

Figure 2. GBR surgery with implantation. (A) The surgical site was opened with careful removal of the remaining fibrous tissue. **(B)** The alveolar ridge was modeled using a manual bone scraper **(C, C')** The bone collected with the bone scraper was gathered in a small surgical pot. **(D)** Four implants were placed. A significant part of their collar (around 4mm long) remained outside of the bone. **(E)** The collected bone was grafted around the implants. **(F)** The regenerative chamber was isolated with a titanium mesh blocked with 2 screws. **(G)** The site was finally covered with a pericardium membrane. **(H)** Sutures were finally performed tight.

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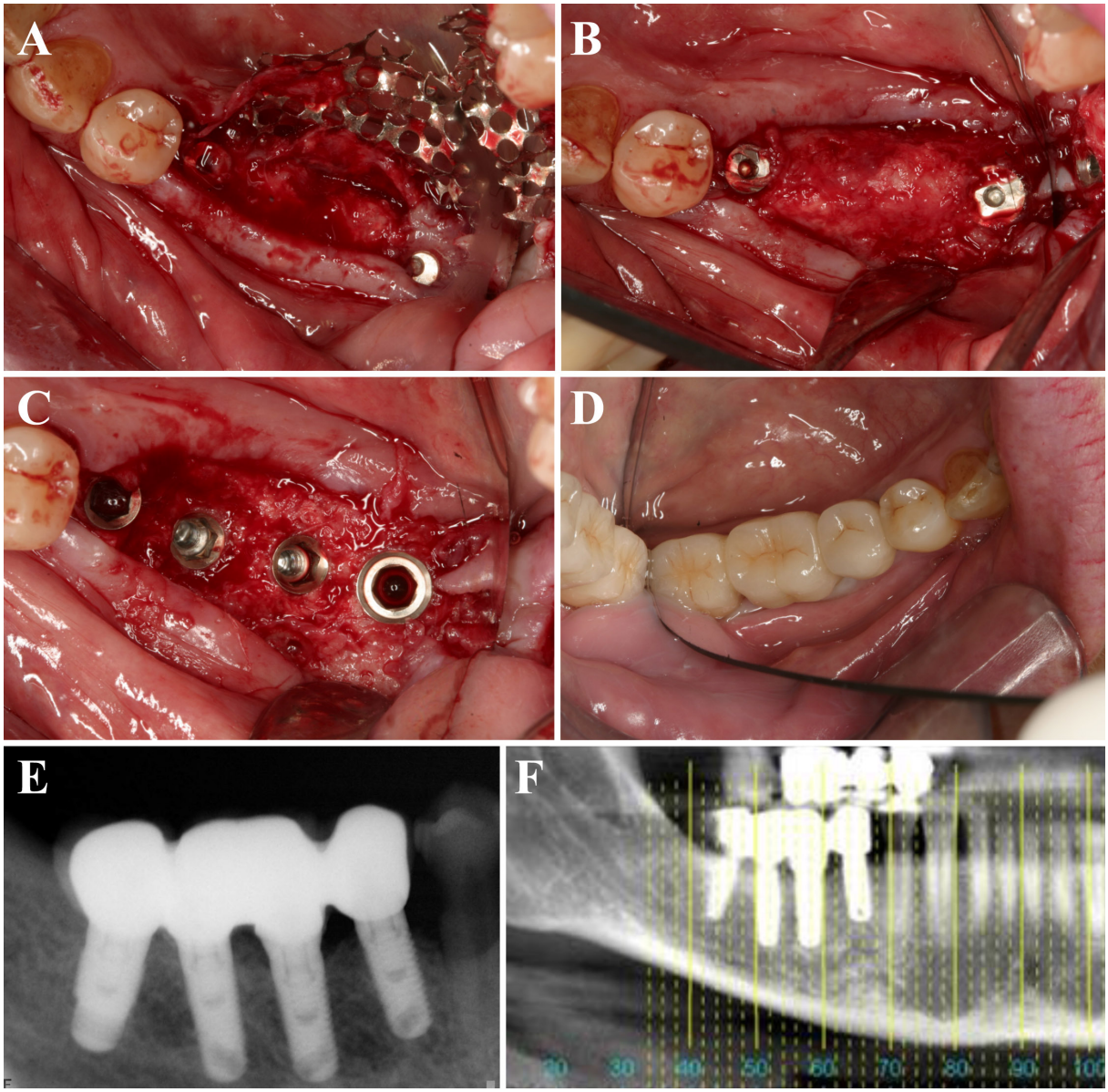

Figure 3. Second step surgery and prosthetic phases. (A) Five months after the GBR surgery, the surgical site was reopened and the titanium mesh was removed. **(B)** The alveolar ridge was well regenerated and new bone even covered the head of the implants. **(C)** Cover screws were removed and trans-gingival screws were placed. **(D)** After healing, an implant-supported bridge was placed. **(E)** Follow-up after 6 months revealed a stable peri-implant bone tissue. **(F)** Follow-up CT scanner after 1 year.

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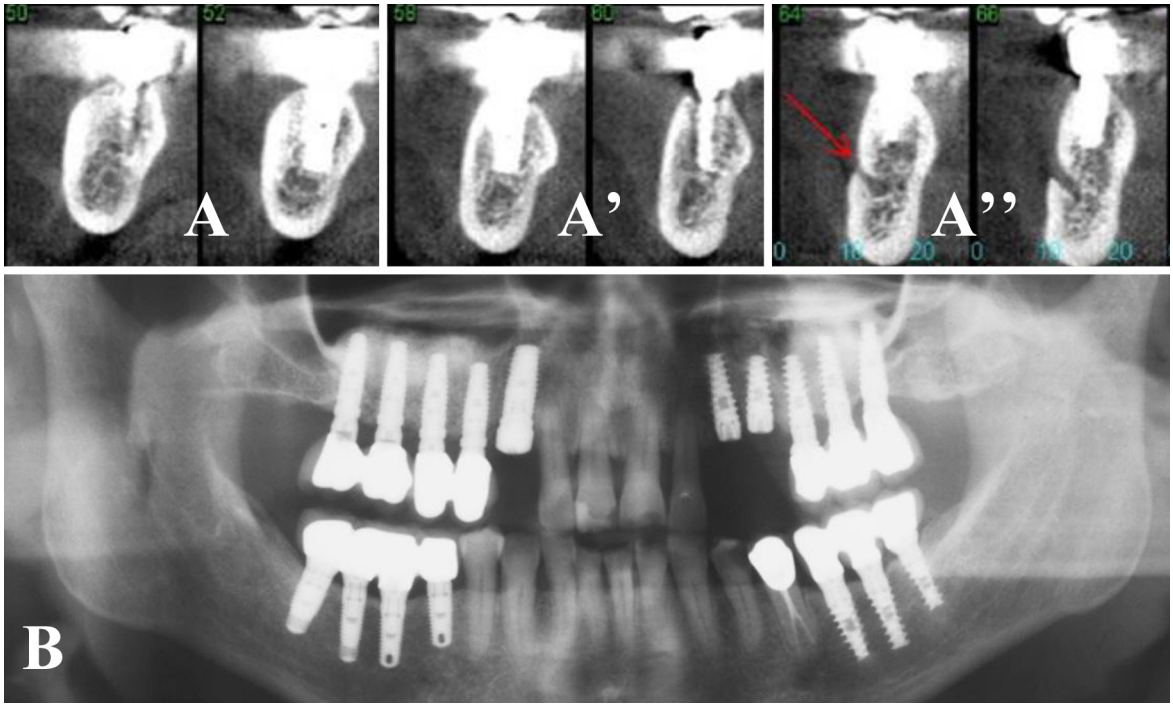

Figure 4. Radiographic follow-up. (A, A', A") The CT scanner after 1 year revealed stable peri-implant bone tissue and showed the proximity between the implant tips and the mandibular nerve. **(B)** Follow-up after 14 years. The implants were functional with a stable peri-implant bone tissue.

3. Discussion

One of the most important issues of the GBR technique in the posterior mandible is the risk of dehiscence of the gingival flap **[1]**. In case of perforation of the soft tissue, the titanium barrier can be very quickly contaminated with oral bacteria and the regenerative chamber is often impossible to protect and recover. In such situation, the grafted material must be removed with the membranes, and the final clinical situation may be even worst than the initial situation of the patient. In this case, we tried to reduce the risk of dehiscence by combining several techniques and materials.

First, the residual alveolar ridge was remodeled during the collection of the bone fragments with the scraper. This allowed to reduce the potential hard angles of the bone that may be too aggressive for the gingival cover after sutures. Moreover, by reducing laterally the bone volume, the flap became *de facto* a little bit more extended than the remaining alveolar ridge and some covering surface of the flap was therefore gained.

Second, the second molar was kept temporarily after the S-GBR main surgery, in order to protect the regenerative chamber from mechanical constraints. The presence of this residual tooth was an easy way to reduce the stress on the surgical area during the early critical phases of healing.

Finally, a pericardium membrane was used above the titanium mesh in order to promote the healing of the soft tissue, but also to protect the gingiva from the potentially sharp angles of the titanium mesh. If such case was treated nowadays, the use of L-PRF

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(Leukocyte- and Platelet-rich Fibrin) membranes would be probably beneficial above or in replacement of the pericardium membrane. L-PRF is a fibrin membrane rich in growth factors **[8,9]** and is very useful to promote gingival healing and quick wound closure **[10]**.

The bone levels after 14 years were very stable in this case. The simultaneous implantation during the GBR surgery seems a very reasonable approach, as the presence of the implants in fact reinforced the regenerative chamber. The implants serve as tent pegs under the barriers and membranes, add some biomechanical strength to the regeneration compartment during the early sensible phases of healing and can reduce the impact of mechanical constraints on the reconstructed ridge. Finally, the implants also serve as pillar to guide the growth of bone in the chamber, and the organization of the regenerated bone directly around the implants may promote a better long-term integration of the implants in the bone volume under reconstruction. This S-GBR approach is similar to the various techniques of simultaneous implantation and sinus-lift, where the implants serve as space maintainer like tent pegs with excellent clinical results **[11]**.

As a conclusion, GBR remains a difficult surgery that requires careful planning and experience. When this technique is well performed and succeeds, the long-term results are very stable. This article also shows that the concept of simultaneous implantation and GBR should be in fact perceived as a slightly different concept, named S-GBR, as the presence of the screws has logically a significant impact in the therapeutic strategy and final outcome.

Disclosure of interests

The author has no conflict of interest to report.

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Clinical case letter

Immediate implantation and peri-implant Natural Bone Regeneration (NBR) in the severely resorbed posterior mandible using Leukocyte- and Platelet-Rich Fibrin (L-PRF): a 4-year follow-up

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1. Introduction

In the severely resorbed posterior mandible, the placement of dental implants in ideal position is often compromised by the significant post-extraction centrifuge alveolar bone resorption. The shape of the residual alveolar ridges and the residual bone height above the inferior alveolar nerve often make the area not suitable for direct implantation. Even if the use of short implants offers excellent results when the residual bone volumes are high and wide enough to receive these implants **[1]**, there is no other solution than bone regeneration surgery prior to implant placement when the alveolar ridges are very thin **[2]**. However bone regeneration itself remains a challenge in this area, as the mandibular posterior residual alveolar ridges are always very cortical with a low vascularization and therefore not really adapted to the integration of bone grafting material or regeneration of bone cavities. Finally, the posterior mandible is a place of significant mechanical constraints applied on the bone and gingival tissues during the mastication function, and this can compromise the healing of a bone regeneration chamber, particularly through the risk of soft tissue dehiscence after the regeneration surgery.

To bypass these many traps and disadvantages, we tried to develop a new form of Guided Bone Regeneration (GBR) where both the bone and gingival compartments are reinforced and better controlled. The first element of this strategy is to use the dental implant itself as a space maintainer **[3]** and as a regeneration pillar to reinforce, protect and guide the bone compartment under the GBR barrier. This concept is termed Screw-Guided Bone Regeneration (S-GBR), and the implant is considered as an optimized screw (in comparison to more traditional osteosynthesis screws that can be used in this strategy).

The second element of this strategy is the use of an adequate combination of bone substitute and Leukocyte- and Platelet-Rich Fibrin (L-PRF). L-PRF is platelet concentrate for surgical use (Intra-Spin L-PRF system, Intra-lock, Boca Raton, FL, USA)**[4]**. After centrifugation of 10mL whole blood without anticoagulant, a L-PRF clot can be collected and contains most of the platelet aggregates, leukocytes and growth factors of the initial blood sample within a strong fibrin matrix **[5]**. L-PRF is an optimized blood clot. After compression in an adequate surgical box (Xpression kit, Intra-lock, Boca Raton, FL,

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USA)**[6]**, we can collect a strong membrane with many potential uses in periodontology and implant dentistry **[7,8]**. This membrane releases growth factors and healing proteins during more than 7 days in vitro and promotes cell proliferation and differentiation **[6,9]**.

During bone regeneration surgeries, the use of L-PRF membranes accelerates soft tissue healing and prevents gingival dehiscence **[10]**, thus protecting the bone regeneration compartment. It also stimulates bone tissue integration and remodeling **[11]**. This strategy of combining L-PRF with adequate materials is a form of in vivo tissue engineering and was termed Natural Bone Regeneration (NBR). In this article, we describe the use of L-PRF and simultaneous implantation in a NBR strategy for the treatment of a severely resorbed posterior mandible.

2. Materials/methods and results

A 49 years old female patient came to the implant consultation for a fixed implant-supported rehabilitation of her right posterior mandible. The 3 molars were extracted more than 6 years ago and the patient was wearing a removable partial denture. The patient was a moderate smoker (2 cigarettes per day) and in good general health. The radiographic examination revealed a significant resorption of the bone alveolar ridge in width **(Figures 1A, 1B, 1C)**. The residual bone height was acceptable for direct implantation, but the width was much too slim to place implants in adequate orientation and position.

Using the implant planning software, we observed that an ideal direct implant placement would imply to leave the upper 6mm of each implant outside of the mandibular bone body **(Figure 1B)**: only the lingual face of the implants would be in contact with the residual alveolar bone ridge. As the implant could be stabilized with their lower part within the residual bone, it was decided to perform a direct implantation with simultaneous peri-implant bone regeneration following the S-GBR and NBR principles.

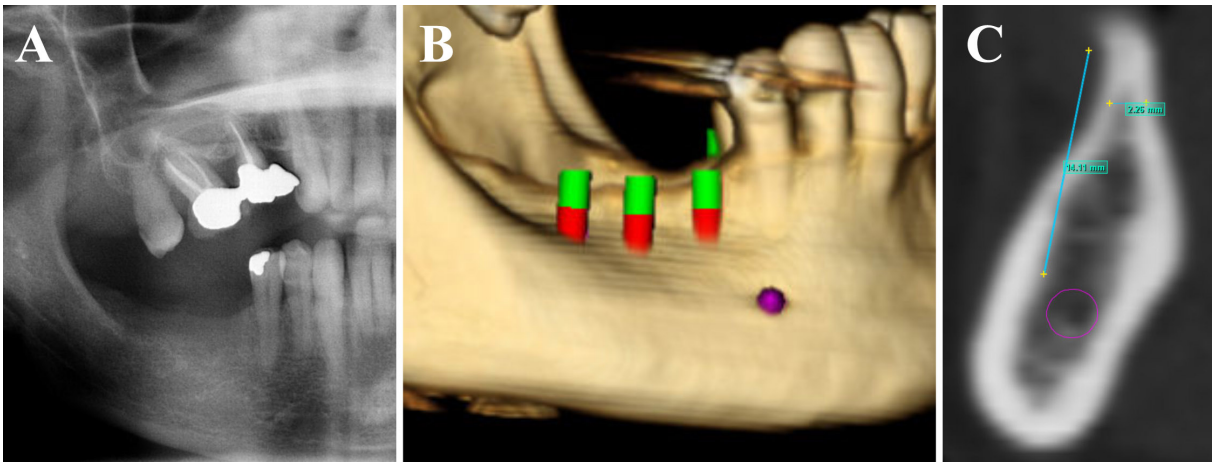

Figure 1. Radiographic examination of a resorbed posterior mandible before implantation. (A) On the panoramic radiograph, the residual alveolar height appeared suitable for implantation. **(B)** The residual bone ridge was very narrow and resorbed. A 3D planning for implants placement illustrated that in adequate positions, around 6mm of the implants length would remain mostly outside of the bone ridge. **(C)** The CT scanner reconstruction showed the slim shape of the upper half of the alveolar crest above the inferior nerve.

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At the beginning of the surgery, L-PRF was prepared using the standard protocol and material (FDA approved/CE marked system marketed as Intra-Spin system and Xpression preparation kits, Intra-lock, Boca Raton, FL, USA) using 8 tubes of 10mL of whole blood. After centrifugation and collection of the L-PRF clots, 8 membranes were prepared for use at the end of the surgery.

The clinical procedure was performed using local anesthesia **(Figure 2A)**. The surgical site was opened and confirmed the slim shape of the residual alveolar ridge **(Figure 2B)**. The implant osteotomies were carefully marked using a piezosurgical device (Piezosurgery, Mectron s.p.a., Carasco, Italy) on the crest along the slim residual wall **(Figure 2C)**. The choice of this instrument was justified by the need of a very accurate osteotomy to be able to block the implants in the small residual bone height: as the residual ridge was very cortical and slim, there was a significant risk of sliding, bone fracture and formation of a bone dehiscence with a classical osteotomy drilling. The piezosurgical cut allowed to remain easily in an appropriate axis and to control accurately the dimensions and position of the implant well **[12]**. The implant osteotomies were then finished using the same piezosurgical instrument, and the implant wells appeared homogeneous and accurate **(Figures 2D, 2E)**, what was in this case a significant key for success.

Three implants (10mm x 3.3mm for the 2 anteriors and 8mm x 3.3mm for the posterior) were inserted carefully in their respective wells (Ossean, Intra-Lock Inc., Boca Raton, FL, USA), and 5 to 6mm of the upper part of the implants remained out of the residual alveolar ridge **(Figure 3A)**. Only the lingual face of the implant was in direct contact with the osteotomy walls all along. It could be noticed the precision of their axis, and the spaces between implants were chosen to have the implant heads in position of tent pegs for the bone regenerative chamber **(Figure 3B)**.

The next step of the NBR strategy was to perforate the cortical bone by drilling 12 holes with a round bur all over the buccal wall of the residual alveolar ridge, following the principles of endosseous stimulation **(Figure 3C)**. This trans-cortical bleeding was a key for the vascularization of the bone regeneration compartment and the proper integration of the bone grafting material. The vestibular face of the alveolar ridge was then covered with a mix of L-PRF and collagenated equine bone material (Gen-Os, OsteoBiol, Tecnoss, Turin, Italy) in a 50/50 volume ratio, in association with a 0.5% metronidazole solution **(Figure 3D)**. All the threads of the implants were largely covered with a significant quantity of material to regenerate a broad alveolar ridge around them.

Three layers of L-PRF were finally added to cover the surgical site and maintain the bone material **(Figure 3E)**. Following the NBR principles, these membranes were used as competitive interposition barrier to protect and stimulate the bone compartment, and as healing membranes to stimulate the periosteum and gingival healing and remodeling. Periosteal incisions were done on the flaps to promote their tension-free closure. The surgical site was sutured with non-resorbable sutures (silk 4.0, Hu-Friedy, Chicago, IL, USA)**(Figure 3F)**. A post-surgical panoramic radiograph showed the adequate position of the implants and the grafted area appeared slightly radio-translucent **(Figure 3G)**. Sutures were removed after 12 days. The post-surgical follow-up was uneventful.

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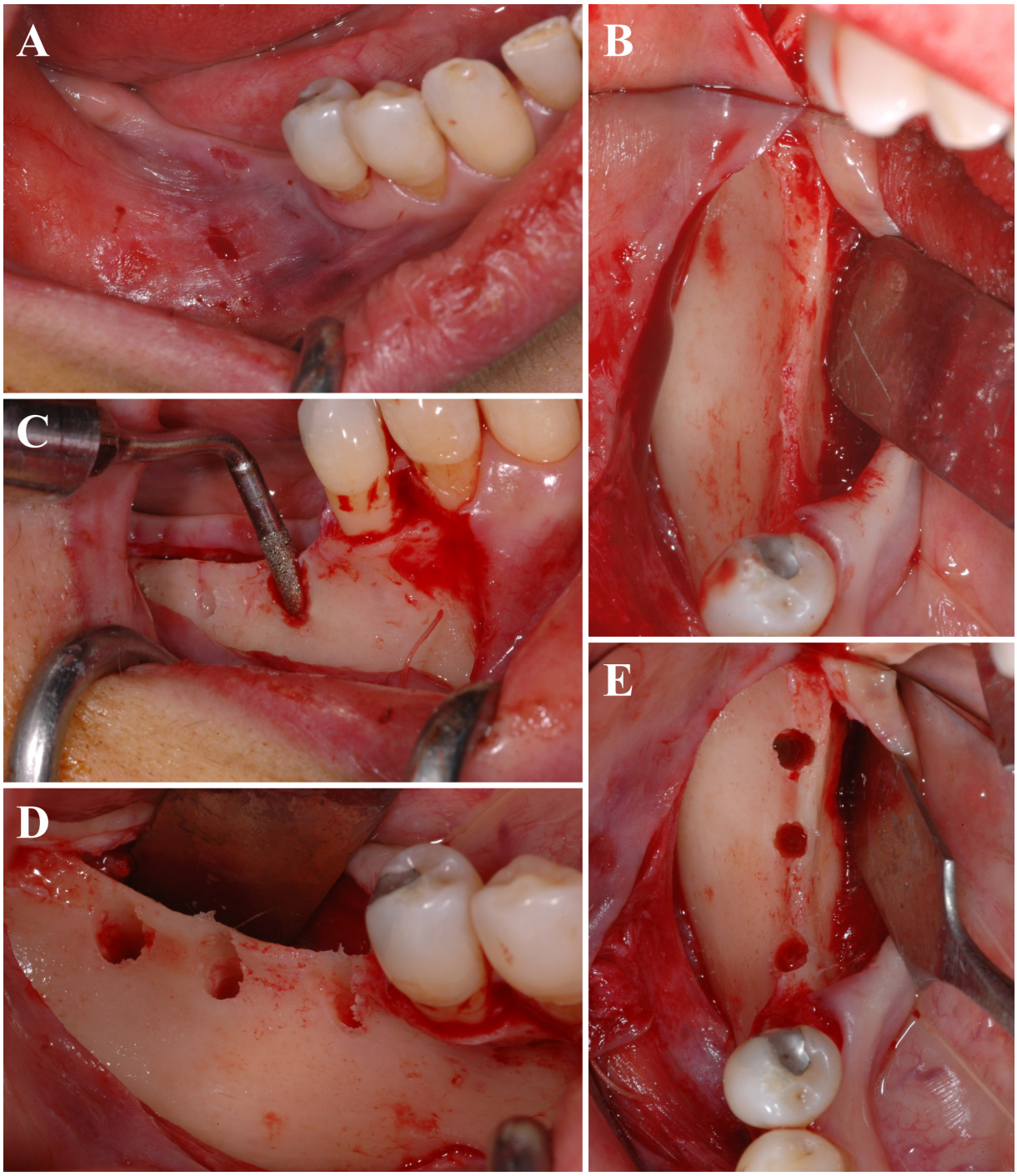

Figure 2. Simultaneous implantation and NBR in the resorbed posterior mandible: osteotomy phase. (A) Initial situation. **(B)** The alveolar ridge was very narrow. **(C)** The implant osteotomy positions were carefully marked along the narrow crest using a piezosurgical instrument. **(D, E)** The implant wells were prepared with the piezosurgical lancet in order to obtain a very accurate and non traumatic osteotomy.

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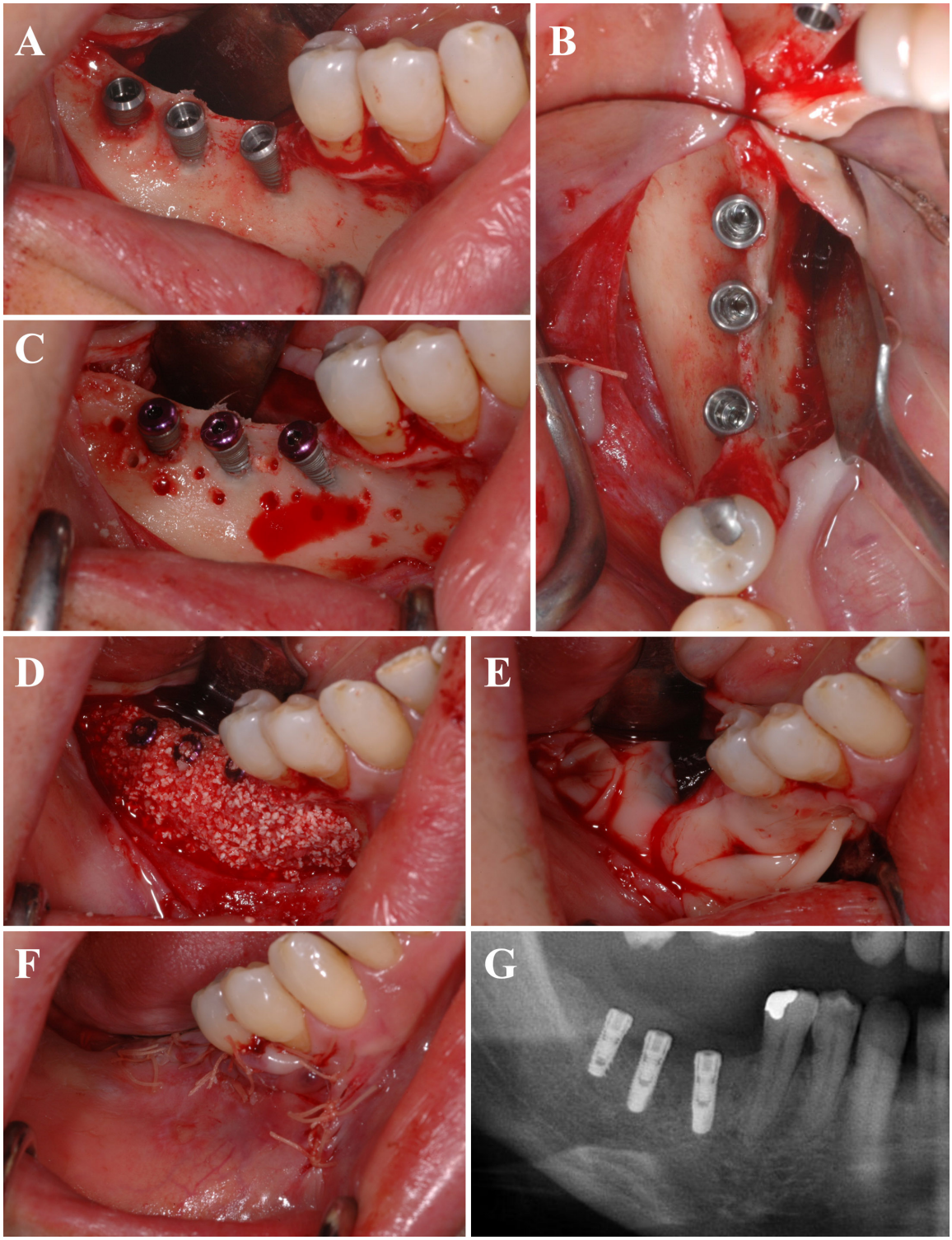

Figure 3. Simultaneous implantation and NBR in the resorbed posterior mandible. (A) Three implants (Ossean, Intra-Lock, Boca-Raton, FL, USA) were inserted. Their vestibular faces remained 5-6mm out of the bone ridge. **(B)** The implant collars were in direct contact only with the buccal wall of the narrow residual alveolar ridge. **(C)** Twelve endosseous stimulations holes were drilled with a round bur. **(D)** The vestibular face of the alveolar ridge was grafted with a mix of L-PRF and collagenated equine xenograft bone (Gen-Os, OsteoBiol, Tecnoss, Turin, Italy) in a 50/50 volume ratio, in association with a 0.5% metronidazole solution. **(E)** Three layers of L-PRF membranes were added on the grafted area in order to protect the bone material and to stimulate periosteum and soft tissue healing and remodeling. **(F)** Periosteal incisions and tension-free sutures were done. **(G)** Post-surgical panoramic radiograph.

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Four months after surgery, the keratinized gingival tissue above the implants appeared thick and strong **(Figure 4A)**, and the trans-gingival healing screws could be connected. A few weeks later, the screws were removed and the gingival tissue appeared thick and healthy on a quite broad regenerated alveolar ridge, without dehiscence **(Figure 4B)**. The final implant-supported bridge was placed. The clinical and radiographic follow-up was organized each 6 months during the first year and then each year. Four years after the treatment, the rehabilitation appeared stable, functional and esthetic **(Figure 4C)**. The radiographic follow-up did not show any significant peri-implant bone loss. The peri-implant tissues remained at the same level around the implant collars, and no dehiscence appeared **(Figure 4D)**.

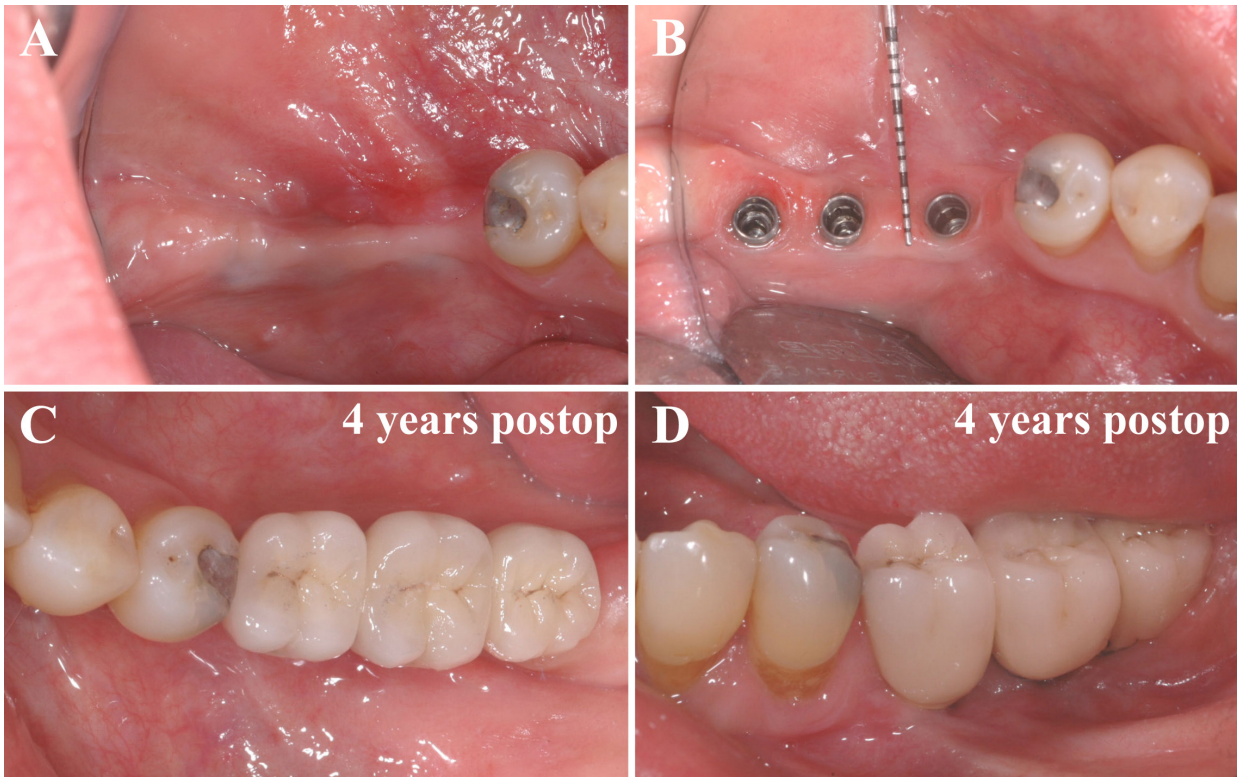

Figure 4. Prosthetic phase and follow-up. (A) Four months after surgery, the keratinized gingiva above the implants appeared thick and mature. Trans-gingival screws were connected. **(B)** After healing, the regenerated alveolar ridge was quite broad and covered with thick gingiva. The implant-supported bridge was placed. **(C)** Four years after treatment, the rehabilitation was stable and functional. **(D)** Tissues around the implant collars appeared stable. No bone loss or gingival dehiscence was observed.

3. Discussion

The general concept of NBR is to promote the simultaneous regeneration of the bone compartment and the gingival tissue above, through the use of L-PRF membranes as interposition and healing material: this is the synchronized regeneration principle. On one side, L-PRF stimulates early wound closure and longer-term gingival maturation **[10]**, thus protects the bone compartment; on the other side, L-PRF supports the bone growth in the bone chamber **[11]**.

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In the NBR strategy, the bone grafting material is in general mixed with a L-PRF clot cut in small pieces, following a 70/30 or 50/50 volume ratio. The objective of this mixture is to help the rapid vascularization of the bone grafting material through the veins of L-PRF fibrin matrix making the bridge between bone particles and allowing a quick new bone growth, while the xenograft material serves as space maintainer for the regenerative volume and supports the nucleation and accumulation of newly formed bone matrix. The concept of the NBR strategy is to promote a complete remodeling of the bone materials and to regenerate *in fine* a natural bone volume. For this reason, the choice of the bone material to associate with the L-PRF is a key element of the definition of the technique. As the literature about bone materials is very controversial and commercial **[13]**, there is no real consensus on the adequate material to use. However, following our experience, the NBR functions in priority with collagenated bone materials, and the material used in this case is commonly employed in our NBR surgeries.

In this case, the choice of the implant may have also a significant impact on the final clinical outcome. Indeed, in this concept of S-GBR, the implant functions as a regenerative pillar and should be an ideal optimized screw for bone growth and regeneration. Therefore, care must be taken to select an implant with an adequate macrodesign and surface which must be at least osteoconductive and maybe osteoinductive **[14]**. Implant with surface pollutions must be avoided. In this case, we used a microrough implant with a Calcium Phosphate low impregnation and nanoroughness, with validated surface patterns and biological properties (Ossean surface)**[15]**. This probably contributed to the excellent results which have been observed with this protocol since more than 5 years.

As a conclusion, the NBR concept gives promising results and is the natural complement of the S-GBR principles. These concepts must now be validated on longer-term and with large series. The choice of materials to combine with L-PRF in these strategies remains an important research question.

Disclosure of interests

The authors have no conflict of interest to report.

Acknowledgement

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Clinical case letter

Preimplant reconstruction of the severely resorbed posterior mandible using the Sandwich technique with piezosurgical osteotomy and Leukocyte- and Platelet-Rich Fibrin (L-PRF): a 5-year follow-up with histological controls

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1. Introduction

The implant-supported treatment of the resorbed posterior mandible is often difficult due to the significant centrifuge resorption of the mandible alvolear ridge after extraction and the proximity of the large nervous-vascular pedicle in the mandibular canal within the mandible body. The residual alveolar ridges can have many different shapes and volumes, and the position of implants is often a challenge. To reconstruct the bone volume prior to implant placement, many techniques have been proposed, but no real consensus exists on what would be the ideal solution or combination of treatments. The use of bone grafting remains a difficult approach that requires experience and skilled clinicians, as the strong cortical bone of the mandible body does not integrate easily bone substitutes or even autologous bone grafts. The risk of partial or complete failure remains significant in the treatment of this area.

In order to bypass the risk of rejection of the bone graft from the cortical bone layer, several techniques were proposed to promote the bone regeneration by splitting the mandibular residual bone ridge and separating a mobile segment to create a medullar space. In this space, bone can be grafted or space can be maintained alone (with a natural blood clot) to regenerate the chamber. Many forms of these techniques exist, such as lateral expansions (where the space is maintained by the dental implants)**[1,2]** or distraction osteogenesis **[3,4]**.

A concept of "sandwich" technique was proposed already a long time ago **[5]**, and many authors suggested various forms of evolution **[6,7]**. In this technique, a cortical bone segment is split and maintained in higher position through the use of screws and plates. The space between the mandible body and the fragments is then filled with some autologous bone or bone biomaterials.

Like for all bone grafting techniques, particularly in the posterior mandible, important issues of this technique are the risk of mechanical and biological constraints on the surgical area and the risk of gingival dehiscence above the grafted area. The gingiva is the only protection against the contamination of the bone regenerative compartment. Moreover, this surgery is very delicate and the use of adequate instruments and procedure is very much necessary to avoid strong inflammatory reactions and bone resorption. The addition of platelet concentrates for surgical use **[8]**, particularly of L-PRF, was already advocated as a

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healing and interposition material in several clinical situations **[4]**, in order to simplify surgical procedures and improve bone and soft tissue healing **[9,10]**.

In this article, we describe a modified version of the sandwich technique, using piezosurgical instruments for non-traumatic osteotomy and L-PRF (Leukocyte- and Platelet-Rich Fibrin) as regenerative and protection material for bone and gingival tissues of the expanded area.

2. Materials/methods and results

The patient was a 53-year old woman, in good general conditions and non-smoker, looking for the rehabilitation of her lower left region. The computed tomography CT-Scanner radiographs revealed a significant resorption of the alveolar bone with a limited bone height (5-6mm) above the mandibular nerve and a deformed curved shape of the residual bone **(Figures 1, 2A)**. Several practitioners already considered the alveolar crest was not suitable for implantation. A treatment plan including a "sandwich" technique was proposed, in order to gain vertical height and to obtain a more homogeneous horizontal shape of the alveolar ridge.

The clinical procedure was performed using local anesthesia and conscious sedation. L-PRF was prepared using the standard protocol and material (marketed in a FDA approved/CE marked kit as Intra-Spin L-PRF, Intra-lock, Boca Raton, FL, USA) using 8 tubes of 10mL of whole blood. After centrifugation and collection of the L-PRF clots, 8 membranes were prepared to be used at the end of the surgery.

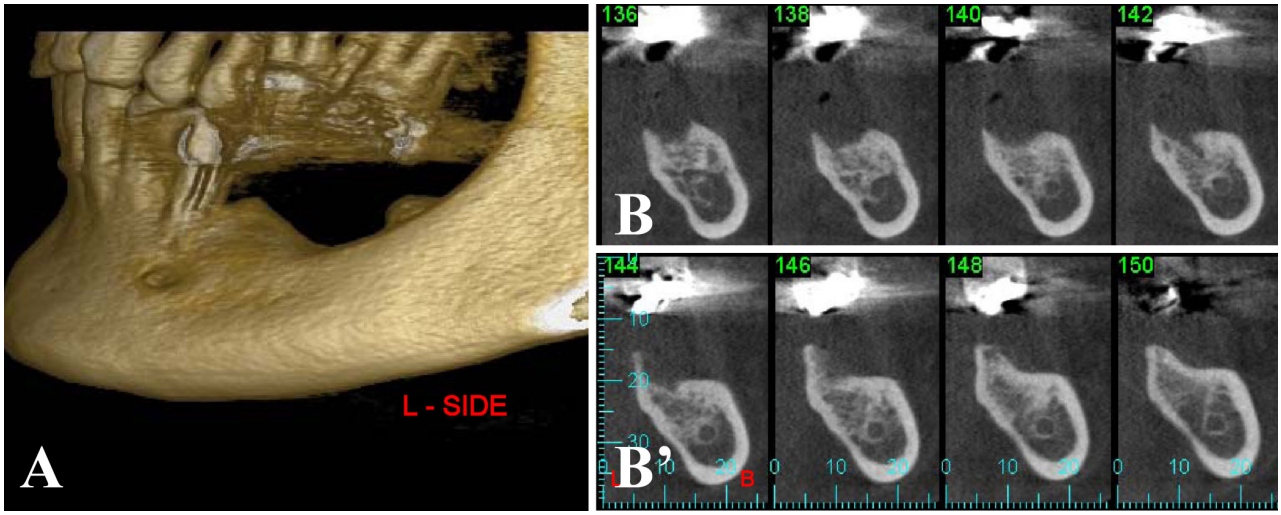

Figure 1. Presurgical CT scanner examination. (A) The residual alveolar ridge was significantly resorbed in height but offered significant volumes in width. **(B, B')** The residual bone height was around 5-6mm and the mandible body shape was not suitable for adequate direct implantation.

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A full muco-periostal flap was raised in order to have a clear access to the cortical bone body of the mandible. Two vertical and one horizontal deep cuts were made using the piezosurgical lancet (Piezosurgery, Mectron s.p.a., Carasco, Italy) on the buccal wall of the alveolar ridge **(Figure 2B)**. Care was taken to keep the lingual part of the muco-gingival flap attached to the cut bone fragment, in order to maintain a natural blood supply to the mobile bone fragment. The bone segment was raised using a chisel to obtain a rotational elevation up to 7mm **(Figures 2C, 2D)**. The segment was finally stabilized with bone fixating osteosynthesis plates and screws (Biomet 3I, Palm Beach Gardens, FL, USA), leaving a regenerative chamber between the mandible body and the repositioned segment **(Figure 2E)**. Holes for endosseous stimulation were performed with a surgical bur on the mandible body along the regenerative chamber, in order to promote bleeding, cell migration and tissue integration **(Figure 2E)**. An osteoinductive allograft material (Regenaform, Exactech Inc, Gainesville, USA) was then prepared by mixing with L-PRF clots (2 membranes cut in small pieces) following a ratio of 1/3 L-PRF, 2/3 material. The material was then packed within the regenerative chamber and around the segment, in order to regenerate a homogeneous alveolar ridge **(Figure 2F)**. Six L-PRF membranes were then used to cover and protect the surgical site **(Figure 2G)**. The flap was prepared with periosteal incisions in order to cover the surgical area properly and sutured using 3/0 vicryl sutures **(Figure 2H)**. Post-surgical follow-up was uneventful, no mandibular nerve paresthesia was noticed and sutures were removed after 8 days.

Five months later, the gingival tissue appeared mature on a wide alveolar ridge **(Figure 3A)**. CT scanner was done and revealed a homogeneous bone volume after bone regeneration of the crest **(Figure 3B)**. The surgical site was reopened to remove the osteosynthesis plates and screws **(Figure 3C)**, and 4 bone biopsies were collected with a trephine in the expected places of the implants. Finally, the 4 implant osteotomies were finished with the adequate drill **(Figure 3D)** and 4 internal connection implants were placed (Biomet 3I, Palm Beach Gardens, FL, USA), all 4mm in diameter and respectively 13mm, 11.5mm, 10mm and 10mm from mesial to distal. Three months later, the trans-gingival screws were placed. After healing, an implant-supported bridge was performed **(Figures 3E, 3F)**. The follow-up was organized each 6 months the first 2 years, and then each year.

The four bone biopsies were fixed in 10 % buffered formalin, dehydrated in alcohol, embedded in resin and cut following the Exakt non-decalcified protocol for cutting-grinding histology (Exakt, Norderstedt, Germany). Each cut was grinded down to 40 µm and stained with Van Gieson´s picro-fuchsin. On these histology sections, no infection or inflammatory reactions were observed. Most of the sample was organized with a medullar viable bone **(Figure 4A)**, covered with compact cortical vital bone at the top of the sample **(Figure 4B)**.

The last control after 5 years **(Figure 4C)** showed very stable alveolar bone ridge volume and peri-implant bone and soft tissues.

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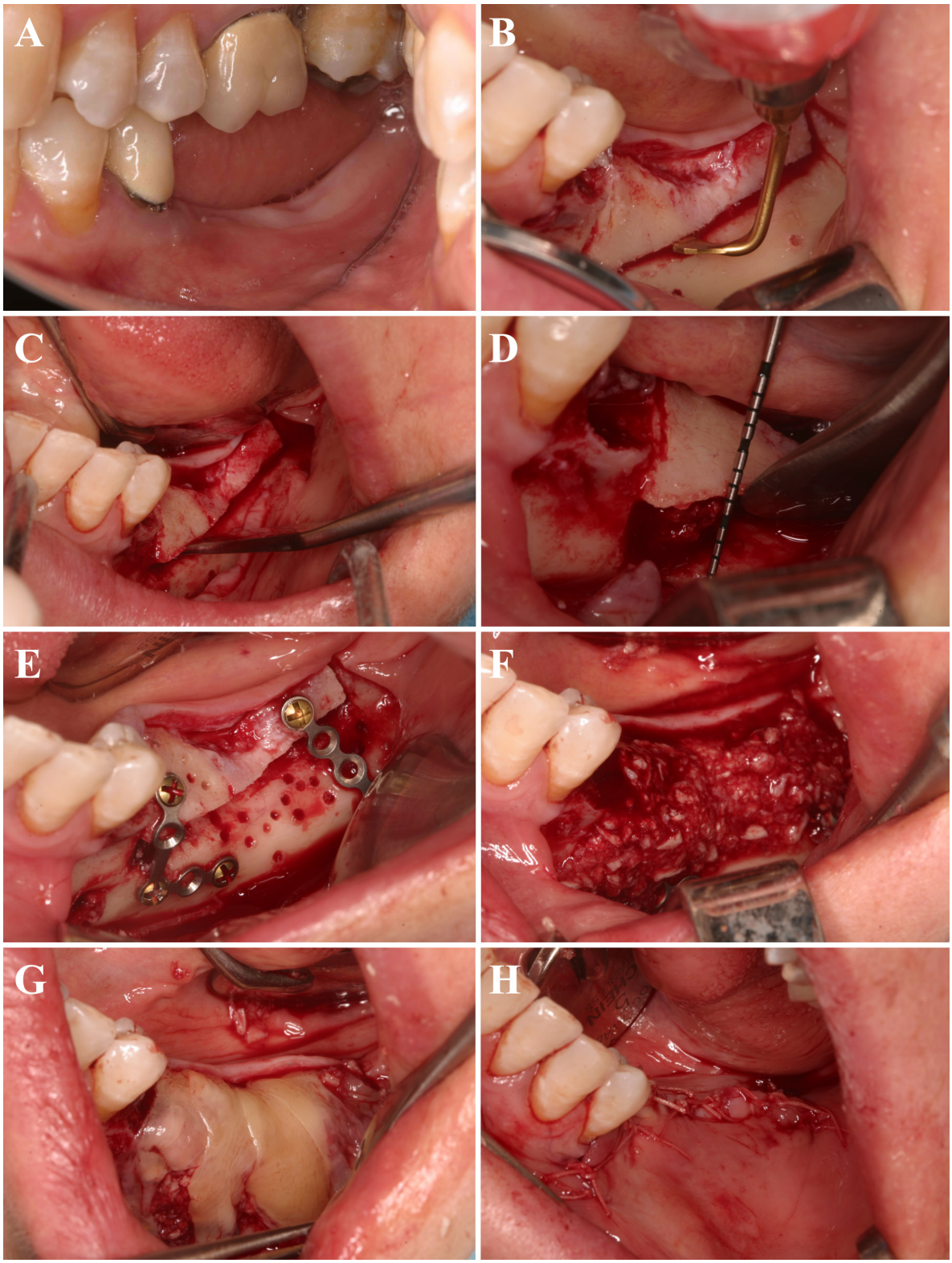

Figure 2. The bone reconstruction surgical phase. (A) The prosthetic space between the maxillary teeth and the mandibular ridge was very high due to the significant mandibular bone resorption. **(B)** Three deep incisions were performed with a piezosurgical lancet to split a large bone segment. **(C)** The segment was separated and lifted with a chisel. **(D)** The fragment was stabilized around 7mm high with a movement of rotation. **(E)** The bone segment was then stabilized with 2 osteosynthesis plates and screws, and the cortical site was activated through endosseous stimulation holes. **(F)** The area was grafted with a mix of bone substitute with L-PRF clot. **(G)** The whole site was then covered and protected with 6 L-PRF membranes. **(H)** The site was sutured.

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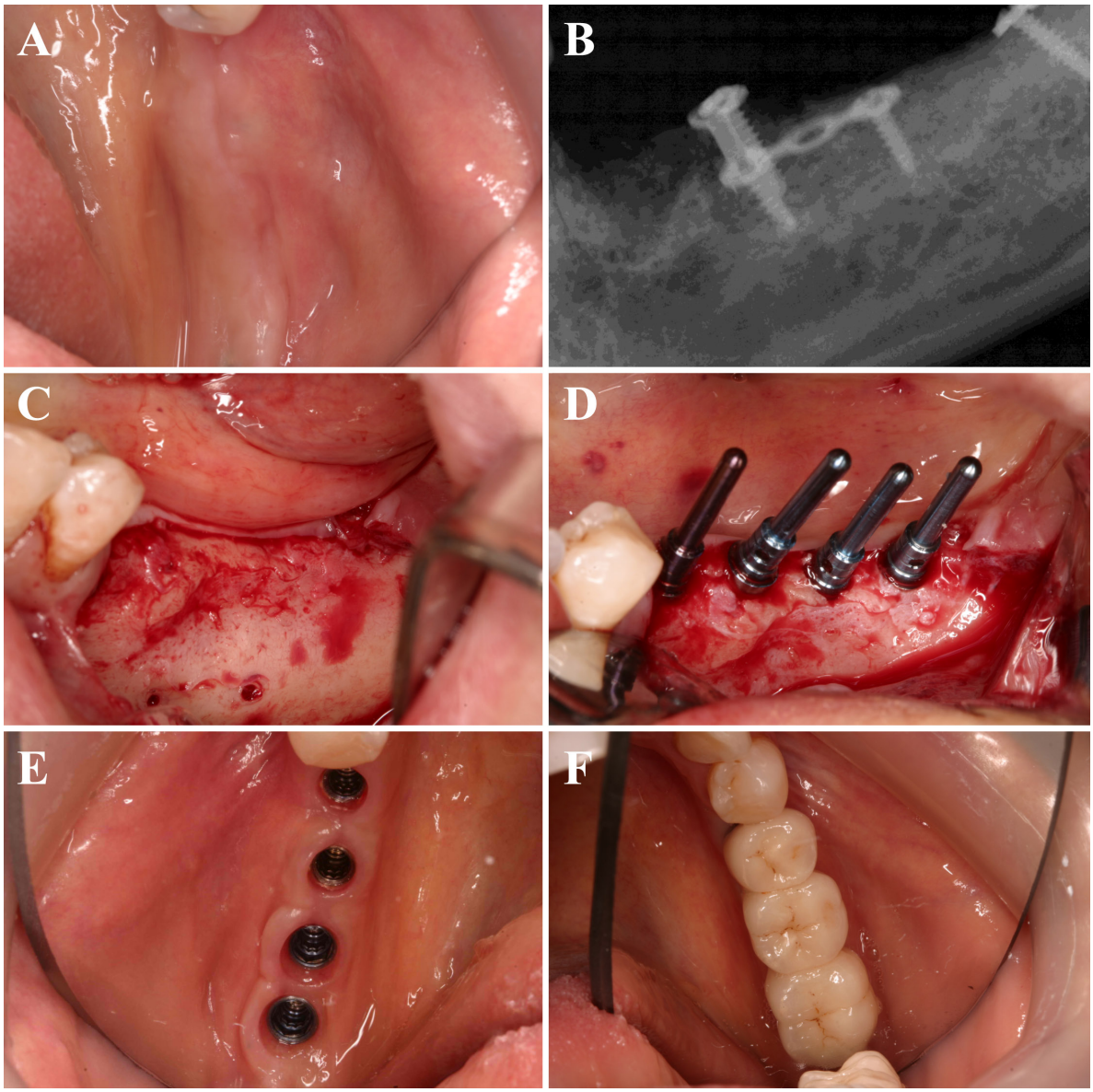

Figure 3. The implant phase. (A) Five months after the bone surgery, the gingival tissue was healed and matured. **(B)** Radiographic follow-up confirmed the proper regeneration of the bone volume. **(C)** Osteosynthesis plates and screws were removed, and the regenerated alveolar ridge appeared homogeneous and well shaped. **(D)** The regenerated bone volume allowed to perform the implant osteotomies in ideal positioning. Implants were then placed. **(E)** Three months after implantation, the trans-gingival screws were placed. After healing, a strong and mature peri-implant gingival tissue could be observed around all implants. **(F)** An implant-supported bridge was finally placed.

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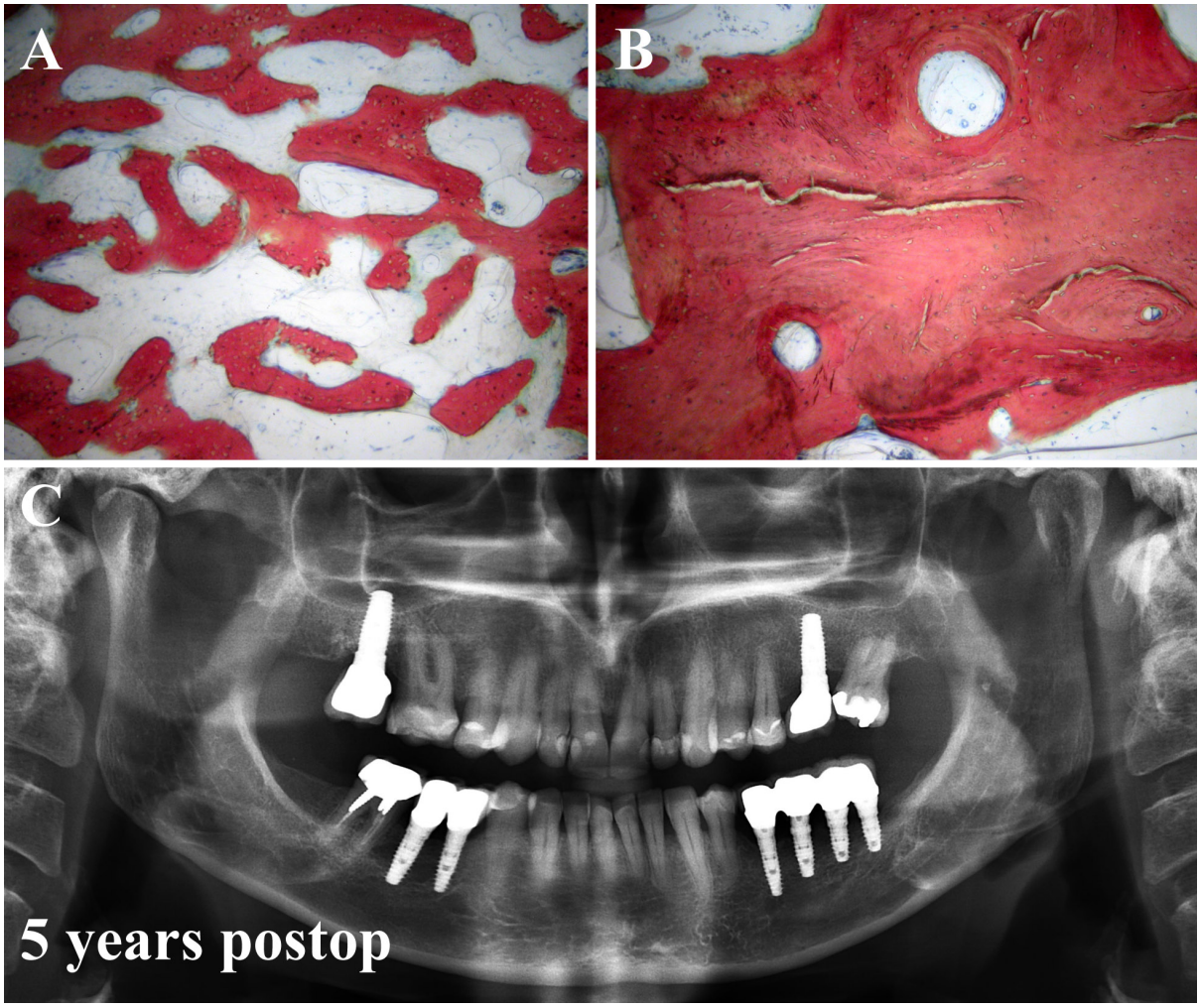

Figure 4. Histological findings and follow-up. (A) Histological analysis of the bone biopsies showed a vital medullar bone in most of the sample of regenerated ridge. **(B)** The top of the sample was also made of some strong cortical layer. **(C)** The 5-year clinical and radiological follow-up revealed a stable implant-supported rehabilitation with no visible peri-implant bone loss.

3. Discussion

The development of various forms of osteotomies and expansions is already an old and well-documented approach in modern implant dentistry **[1,3,6,7]**. This concept is interesting as direct grafts are always difficult to integrate on the very cortical bone of the posterior mandible. However, even if the expansions techniques are well known, their use in daily practice remains limited to a relatively small number of surgeons, as the success of these therapeutic strategies remains very dependent on the skills and experience of the practitioners.

In order to improve the feasibility of these techniques, the use of various surgical adjuvants and improved surgical instruments should be considered with care and interest. The piezosurgical lancet was already advocated as an adequate non-traumatic instrument for the splitting of alveolar ridges in the various kinds of expansions and distraction osteogenesis techniques **[2]**. The cut power of the instrument is lower than a traditional surgical bur, but

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the cut is safer, less traumatic and finally more accurate **[11]**. More important, the ultrasonic vibrations of the instruments are very helpful to split solid pieces, what makes the final split of the bone fragments much easier **[12]**. This instrument can be considered as a gold standard for this kind of surgery.

The use of L-PRF as regenerative and interposition material in this kind of surgery has never been published before. L-PRF is a platelet concentrate for surgical use, prepared by centrifugation of a blood sample **[8]**. The final clot or membrane contains most of the platelets and half of the leukocytes of the initial blood sample **[13]**. This membrane releases growth factors during at least 7 days **[14]** and has a strong proliferation and differentiation effect on bone and gingival cells **[15]**. In this application, the L-PRF is used to help the vascularization and bone regeneration of the grafted bone volume, but its main function is the protection of the regenerative chamber **[10]**. The L-PRF layers stimulate the healing and maturation of the gingival tissue and avoid the risk of soft tissue dehiscence around the grafted material **[9]**. Moreover, a strong gingival maturation is always noticed in the area covered with many layers of L-PRF, and this was also observed in this case, particularly for the peri-implant papilla **[9,10]**.

As a conclusion, the use of L-PRF as surgical adjuvant and piezosurgical devices offers new opportunities to make this surgery safer and more predictable. It remains a difficult surgery that requires adequate technical skills and experience, but the reduction of bone stress and improvement of healing through the use of these materials clearly make it more accessible.

Disclosure of interests

The authors have no conflict of interest to report.

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Clinical case letter

Implantation in the resorbed posterior mandible using computerized planning and surgical guides to bypass the mandibular nerve: a 2-year follow-up

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1. Introduction

The treatment of the resorbed posterior mandible remains a challenge in modern implant dentistry. After tooth removal, the centrifuge bone resorption is always very significant, and often accelerated by the mechanical constraints related to removable prostheses. The presence of the large vascular-nervous pedicle - the mandibular alveolar nerve - within the mandible body reduces significantly the volume of implantable bone and remains the main obstacle to implantation in the resorbed posterior mandible.

Even if the bone quality at the mandible is often high due to its strong cortical organization, this characteristic becomes a real inconvenient for all bone grafting techniques: it is difficult to promote a full long-term integration of a bone graft on the very cortical mandible bone. As bone regeneration or grafting is difficult in this area, another approach for the treatment of the resorbed mandible is to perform a transposition of the alveolar nerve prior to implant placement **[1]**. This technique offers good results **[2]**, particularly with the non-traumatic modern instruments such as piezosurgical lancets **[3,4]**, but it remains a difficult technique that requires an experienced skillful surgeon. Moreover, this technique implies the destruction of a bone layer along the mandible (to get access to the nerve) and several cases of mandibular fracture after nerve transposition and implantation were reported in the literature **[5,6]**.

In some cases, another clinical option could be to bypass the mandibular alveolar nerve using an accurate planning of the implant placement around the nerve. This option has never been published or evaluated before, and the objective of this article is to describe a first evaluation of this therapeutic strategy.

2. Materials/methods and results

A 68-year old male patient required an oral rehabilitation of the lower right mandible. The patient was in good general condition and non-smoker. The alveolar ridges were already significantly resorbed. After careful X-ray evaluation, it was noticed a residual alveolar bone height of 5-6mm above the mandibular nerve **(Figure 1A)**. With this height, it was uncertain to perform a proper direct implantation above the nerve without damaging the pedicle, even with short implants **[7]**. Moreover, the presence of a residual second molar with severe periodontal resorption and the general shape of the mandible body reduced even more the bone volume available for a classical implantation in the physiological axis.

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The use of this residual height was however not fully compromised. This patient mandible posterior body had some interesting characteristics in terms of width and shape, as it seemed possible to insert implants with different axes to avoid the main nerve canal **(Figure 1B)**. It was therefore proposed an original treatment plan with a direct implantation of standard implants bypassing the mandibular nerve: in this strategy, the anterior implant could be placed lingual to the nerve and the two distal implants placed buccal to the canal **(Figure 1C)**.

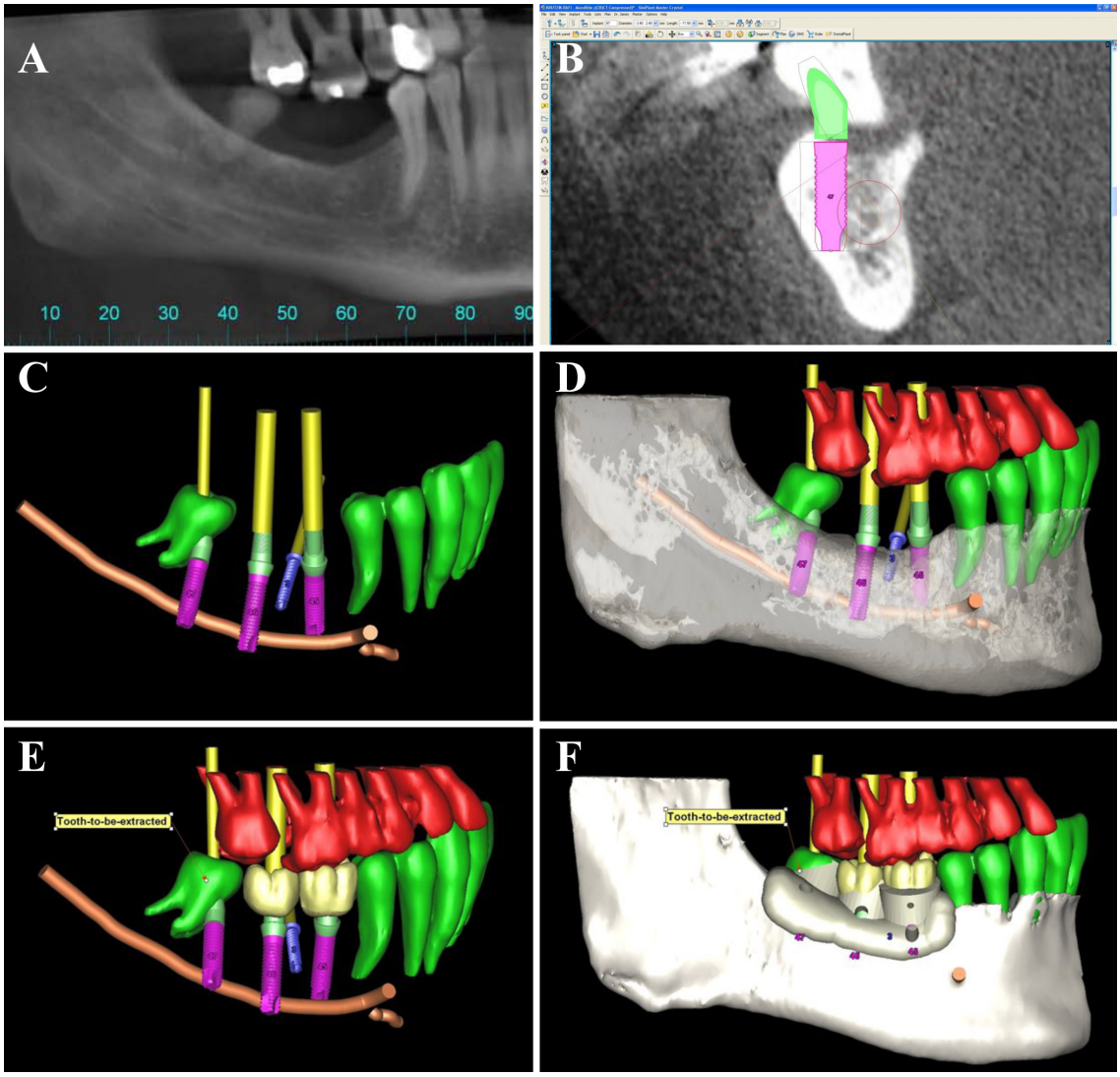

Figure 1. Radiographic analysis and planning. (A) On the CT scanner, the residual bone height above the mandibular nerve was only 5-6mm in the right posterior alveolar ridge. **(B)** The positioning of each dental implant was modeled with the software, using non conventional implantation axis bypassing the mandibular nerve. **(C)** The position of the 3 implants was selected on the Simplant software to remain laterally to the mandibular nerve. **(D)** The axis of each implant was chosen to use all the residual bone volume available and to respect the future orientation of the occlusion forces. **(E)** The position of the implant collars was also directed by the needs of the future implant-supported bridge. **(F)** A final surgical guide was then modeled based on the implant and prosthetic digital planning.

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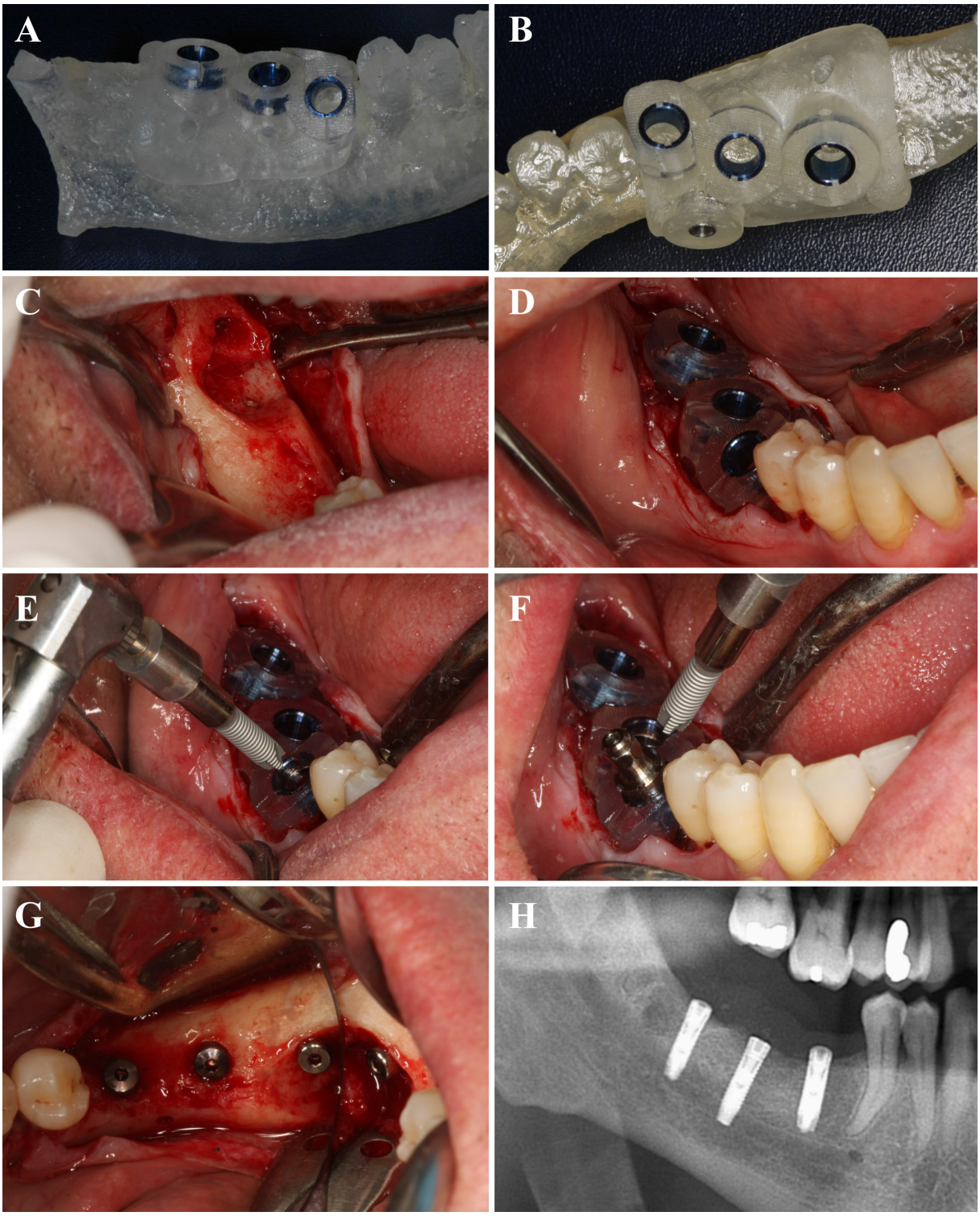

Figure 2. The surgical phase. **(A)** The surgical guide was prepared. **(B)** The guide could be stabilized on the alveolar ridge using a screw in the prepared lateral lingual hole. **(C)** The residual tooth was extracted and a full muco-periosteal flap was raised. **(D)** The surgical guide was placed and screwed in position. **(E, F)** After careful drilling, the implants were placed through the surgical guide. **(G)** The three implants were in position with cover screws. **(H)** The postsurgical panoramic radiograph showed this superposition of the implants and the mandibular nerve as expected.

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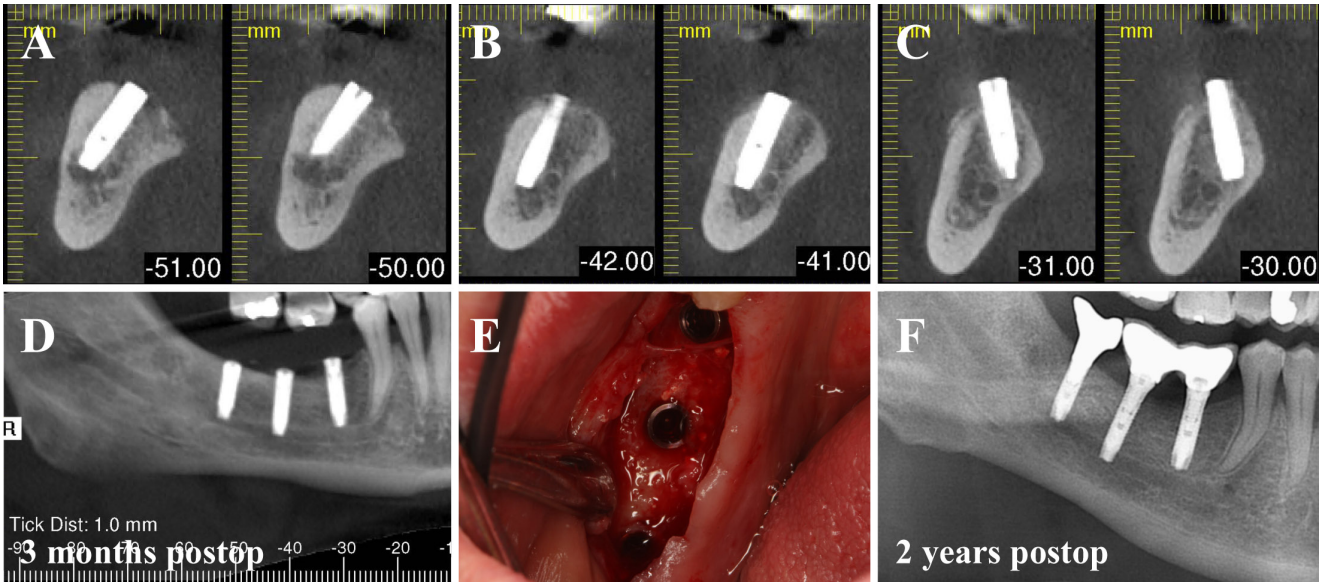

Figure 3. Follow-up. (A, B, C, D) Three months after surgery, a CT scanner was performed and confirmed the exact positioning of each implant. The distal **(A)** and central **(B)** implants were bypassing the nerve in vestibular, the mesial implant was bypassing the nerve in lingual **(C)**. The peri-implant bone tissue was stable **(D)**. **(E)** The implants were then uncovered and trans-gingival screws were placed prior to prosthetic rehabilitation. **(F)** Two years after surgery, the clinical and radiological follow-up confirmed a stable clinical result.

The treatment planning was first accurately modeled. Computerized Tomography scanner DICOM data were converted through the Simplant software (Materialise Dental NV, Leuven, Belgium) in order to visualize the treatment planning. The second right molar was scheduled for extraction during the surgical procedure. Three implants of small diameter (3.25mm) and normal length (13mm) could be placed with specific axes around the nerve, by using all the residual bone volume available **(Figure 1D)**. Care was taken to keep axes compatible with the construction of the functional and stable prosthesis **(Figure 1E)**. This model was then used to order a surgical guide **(Figure 1F)**, in order to place the implants exactly in the best position around the nerve and without damaging the mandible cortical plates. The surgical guide included metal sleeves for implant drills and insertion. The guide was also designed with a fixation screw to guaranty the fixation of the guide in correct position during the surgery **(Figures 2A, 2B)**.

Surgical treatment was carried out under conscious sedation. Local anesthesia was administered and full muco-periostal flap was elevated to have a direct access to the underlying bone ridge. The second right molar was extracted and the site was carefully curetted **(Figure 2C)**. The surgical guide was then placed and fixated with a 2mm diameter screw **(Figure 2D)**. Implant osteotomies were done according to the surgical plan. Three implants (Biomet 3I, Palm Beach Gardens, FL, USA) with a diameter of 3.25mm and with Certain internal connection were placed **(Figures 2E, 2F, 2G)**. Standard sutures were done to close the surgical site. Healing was uneventful. No change in the lip or chin sensibility was noticed after surgery. The post-operatory panoramic X-ray showed the superposition of the implants and nerve on the picture **(Figure 2H)**. Three months after surgery, a 3D examination was performed and showed that the implants were indeed in the

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axis that was planned on the computer, all around the nerve canal **(Figures 3A to 3D)**. The implants were then uncovered **(Figure 3E)** for the connection of the trans-gingival screws and the preparation of the implant-supported bridge. Two years after surgery, the clinical and radiographic follow-up confirmed the stability of the implants **(Figure 3F)**.

3. Discussion

In this clinical situation, several treatment options could have been proposed. However, no approach could be considered as a conventional treatment plan, as there is no consensus or perfect solution for these cases. With this kind of residual height, all options remain quite experimental.

The possibility of nerve transposition technique was not indicated here **[2]** as there was too much bone remaining around the nerve, and the access to the nerve would be too damaging for the mandible: this technique is clearly to be kept for more extreme situations.

The development of short implants is particularly significant in this field nowadays and this approach offers excellent results **[7,8]**. The use of short implants was possible but limited in this case, as the residual bone heights (with 1mm security above the nerve) along the alveolar ridge were below the minimum 6mm that are required to place properly short implants **[7]**. With the available heights, it was uncertain to perform a proper direct implantation above the nerve without damaging the pedicle.

The last option would be the addition of bone graft or the bone regeneration before or during implantation. In this case, as most of the bone resorption was in height and not in width, the addition of a bone graft would be even more uncertain, as mandible bone reconstruction in height is often considered the most difficult treatment in implant dentistry. Therefore the use of the computer-based planning was probably the safest approach here.

Computer-based planning has been developed and advocated since many years in this field **[9]**. It is not only helpful for the accurate placement of implants, but also as an instrument of pre-surgical analysis of bone densities **[10]** or of pre-modeling and visualization of a complex bone reconstructive surgery **[11]**. However, its development is limited by the time and cost the use of this technique is requiring. The planning is time-consuming for the practitioner, the software and the order of the custom-made surgical guide are expensive, while the real need of this approach is mostly limited to complex cases. If this approach is interesting for full-arch bridges **[12]** or the placement of pterygoid or zygoma implants **[13]**, it has a limited relevance for small cases, particularly with experienced practitioners. However in this case, this instrument was very useful to solve a relatively simple but difficult situation.

Even if the CT scan and the software give a feeling of security to the surgeon, it should always be reminded that the accuracy of this planning is not 100% guaranteed, due to the physical limits of the X-ray scanner exam, computer mathematical reconstruction and the potential artifacts that can arise during the phases (for example an imperceptible movement of the patient during the scanner)**[14]**. Therefore, the guide cannot replace a serious experience and surgical skills in case something unexpected in perceived during the surgery. Moreover it is very important to remain careful and reasonable during the treatment planning and keep adequate distances of securities between the wished implant position and the anatomical structures such as the nerve or the cortical plates. Indeed, the perforation of the cortical plate can also have severe consequences if a hemorrhage under the tongue is provoked.

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As a conclusion, this innovative approach cannot be used for all cases, but should be kept in mind as a safe option if all other techniques are considered inadequate and if the anatomy of the patient allows this bypass.

Disclosure of interests

The author has no conflict of interest to report.

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